METALLURGIA

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Wire Rope Testing Machine

Special Design for dealing with large specimens.

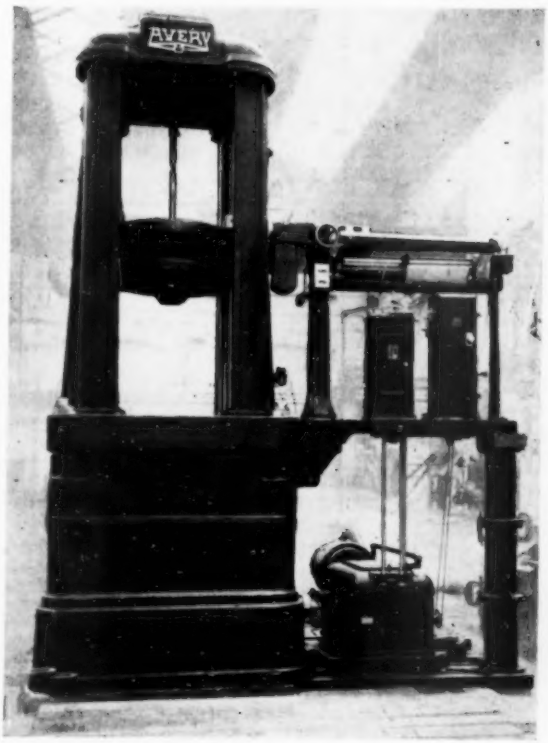

Fig. 1.—Machine completed ready for despatch.

THE various measures that are carried out for the preservation and safeguarding of life in the many industries and occupations of civil existence are generally taken for granted, and so usual has the habit of "safety first" become that the many painstaking tests and experiments in design are frequently passed unnoticed.

Wherever possible, the modern trend is to test complete units of engineering construction on large capacity machines and this is undoubtedly the ideal method. Probably the finest example is the 1,250-tons-capacity testing machine supplied in 1926 by W. and T. Avery, Ltd., to Dorman Long and Co., Ltd., for testing scale models of sections of the Sydney Harbour Bridge.

Incidentally, it is interesting to note that the erection of the bridge proceeded without a hitch, there being no failure whatever of material or component.

In the original James Watt workshop at the Soho Foundry of Messrs. W. and T. Avery, Ltd., another high-capacity machine of a different type has just been completed, and whilst not so powerful as that constructed for Dorman Long and Co., Ltd., it is unique in being the largest vertical compound-lever machine yet made in Great Britain for testing wire cables.

This machine, which is the subject of our article and the accompanying illustrations, has been made to the order of the Canadian Government Department of Mines, and is intended for carrying out tensile tests on wire-rope specimens of 11 in. circumferential maximum, and 6 ft. length unstretched, to a capacity of 1,000,000 lb. We understand that a section of the new wing of the Government House, Toronto, is to be set aside for its installation, whither the machine will be transported by the all-water route via Montreal.

In contrast to the machine supplied to Dorman Long and Co., Ltd., a vertical arrangement has been considered more suitable, due, we understand, to the somewhat confined space allowed by the Canadian authorities, and the fact that tensile tests are admirably suited to this form of load application. The design, however, enables the testing staff to examine the specimen during the process of straining, a clear view being obtained from two sides. Provision is made at the upper or weighing crosshead for lowering into position specimens of maximum size, whilst tackle is being provided on site for handling the specimen and gripping dies.

Reference to the illustration will make clear the main constructional features, comprising a massive three-section base-box, enclosing the main lever system and straining gear, and surmounted by a heavily ribbed cast-steel platform supported on knife-edge bearing on the weighing levers. Bolted to each of the four corners of the weighing platform are robust cast-iron columns supporting at their upper end the weighing crosshead, into which the upper end of the specimen is held in the special form of split grips provided. Projecting through the weighing platform are four 5 in. diameter steel straining screws for holding the cast-steel straining crosshead, in which the lower end of the specimen is held during the test. The lower ends of the straining screws are cut $\frac{1}{2}$ pitch square thread, and work in phosphor-bronze straining nuts, which take the drive from the main worm-shaft. Guide columns bolted to the base-box support the straining crosshead in the course of its travel.

Preparation for a test takes the form of lowering the specimen (specially prepared by fraying the ends of the specimen and casting in lead in conical-shaped moulds) on to the recoil plate, placing the grips in position (the specimen meanwhile being suspended), and lowering the straining crosshead until the recoil plate can be attached, which, when fracture takes place, serves the dual purpose of keeping the grips in position and taking up the reaction.

The straining crosshead is then raised until the upper conical end of the specimen is in such a position that the upper grips can be lowered into position. The specimen is then ready for testing. The strain is applied by means of a protected type reversible motor, driven off an electrical supply of 550 volts, 3 phase, 25 cycles, and fitted with continuously rated slip rings and controlled by a drum-type combined stator and rotor starter.

Coupled to the motor through a clutch operated from the control box is the gearbox, in which the speed is reduced by forged steel sliding gears, mounted on ball-bearing shafts, and working in oil.

The four worm-wheels on the straining screws are all driven off a central worm-shaft coupled to the gearbox, and thrust strains are counteracted by fitting right- and left-hand worms.

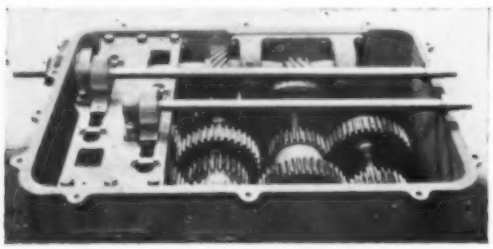

Fig. 2.—Gearbox with cover removed.

Straining speeds of 0·1 in. and 0·4 in. per min. are obtainable, with setting speeds, both forward and return, of 8 in. per min., whilst there is a total straining movement of 8 ft.

So far we have described all the parts on the straining side of the mechanism, where a certain amount of frictional loss is allowable and will not affect the accuracy of the test. The system for measuring the strain, however, must be of a different character, and the load applied must be transmitted to the recording apparatus with the minimum of loss of any description; this has been obtained by means of an accurately designed system of levers floating on knife edges working within the allowed British Board of Trade tolerances of 5 tons per linear inch on the knife edges.

To break down a load of 1,000,000 lb. to give reasonably fine readings on a steelyard of not too massive dimensions, entails an accurate layout of a system of main and transfer levers. This has been obtained by transmitting the load through 9-to-1 ratio main levers, coupled at the centre to a suitably proportioned transfer lever, and then through another transfer lever to the steelyard. By combination with a steelyard ratio of 20 to 1, the load is broken down by 20,000 to 1, and readings of 50 lb. on a micrometer dial fitted to the poise-propelling screw are easily obtainable. A split poise (50 lb. combined, 40 lb. and 10 lb. sepaate) is fitted so that by using the small poise finer readings can be made in conjunction with lower-capacity tests.

Fig. 3.—Poise speed-control mechanism.

Two notable features are the autographic recording apparatus and the electrically propelled and controlled poise.

The last-mentioned may be divided into two separate sections—viz., the propelling system and the electrical control system. The drive for the propelling system is taken from the main gearbox through skew gear to a friction disc drive (which permits the necessary speed variation), and from this point to the poise-propelling screw, via a vertical shaft and necessary gear; the vertical shaft is fitted with a universal joint, which allows the upper portion to be free to oscillate, and enables a small wheel at its end to make driving contact, when required, with either side of a grooved friction pulley arranged on a horizontal shaft connected to the poise-propelling screw.

Electrical control is obtained by means of four contacts arranged in an enclosed box secured to the carrier pillar of the steelyard. One of the contacts is in connection with a bell, another with a buzzer, whilst each of the other two contacts is in connection with a magnet. The magnets are arranged on the standard carrying the steelyard fulcrum. Connection is made through the contacts when a plunger carried from the end of the steelyard engages (according to its position) one of the contacts in the contact box. Thus, when the steelyard rises and makes the first contact, a magnet is energised and attracts the lower end of a small lever which actuates the upper portion of the vertical shaft.

This allows the friction drive to move the poise forward. If the steelyard continues to rise, a second contact is made which sounds a buzzer, and warns the operator to accelerate the poise movement by adjusting the drive to the poise-propelling screw. When the steelyard falls, the first contact rings a bell warning the operator to retard the poise movement, whilst, if the steelyard falls lower, a second contact energises a magnet to allow the friction drive to move the poise "backwards."

A system of change-over switches is provided which permits variation of the sequence of operation.

It will be observed from the illustration that the autographic recorder is immediately behind the steelyard, this position giving good visibility to the operator. The recorder is arranged to enable duplicate records of a test to be taken. The graph paper is secured to a rotatable drum, and the graph is drawn by special pens which are attached to pen carriages working on a propelling screw

Fig. 4.—Wire Rope test specimen.

and arranged parallel to it. Thus, the lateral movement of the pen carriage is in sympathy with the poise and indicates test-load records. The length of the chart may be used to represent various capacities, and to permit of the requisite proportional movement of the pen carriage for the purpose of giving full-size charts at lesser strains a small gearbox provided with four changes is incorporated with the drive to the screw propelling the recorder pen carriage.

To permit the elongation of a specimen to be recorded, the drum is rotated by means of a steel tape carried from the specimen to a pulley on the drum, and is arranged so that the extension indications may be actual, or, if required, may be magnified 5 to 1, or 10 to 1 by means of spur gearing and pulleys.

Among the smaller details of the machine may be mentioned the hydraulic shock absorbers (in addition to the usual rubber buffers), which are fitted under the platform for taking up recoil shock; the massive ball-thrust bearings fitted to the worm-wheels, for taking the upward thrust when the load is applied; the oil pump which supplies oil at pressure to the gearbox, straining screw thrust bearings and other parts; the limit switches for preventing overrun of the straining crosshead, and the generally neat layout of the controls, all of them being within easy reach of the operator.

The machine is to be installed with the control box at floor level, thus the great proportion will be hidden from view, although all parts will be made easy of access.

Finally, some idea of the ingenuity of the design will be gathered when it is known that this machine for applying the very considerable strain of 1,000,000 lb. will go in a maximum space of 18 ft. 6 in. × 13 ft. × 11 ft., whilst the height above the floor will be only 12 ft. Avery's are to be congratulated on the manner in which they have overcome the limitations of the site.

International Association of Testing Materials

The results of the Congress held at Zürich will be of great technical and practical value and will facilitate the progress of scientific research.

THE first Congress of the new International Association of Testing Materials, held at the Swiss Federal Polytechnicum, Zürich, on September 6 to 12, proved to be one of the most interesting ever held. It was the result of the decision of the International Congress for Testing Materials, held in 1927 at Amsterdam, at which it was decided to hold congresses every three or four years, and of which this is the first. It has been organised on somewhat different lines to those usually followed at other meetings of a similar kind. The activities of the Association have been divided into four main groups, and the choice of subjects to be discussed in each group was decided upon by its Permanent Committee after considering recommendations from leading authorities in the participating countries. For this purpose reports on a selected number of subjects were invited from scientific and technical men about two years ago, and the subjects discussed at Zurich were based on a selection from these reports. In this way it was possible to devote the whole of one session to the discussion of a single group of questions, a method which could be adopted with advantage at other meetings of a similar nature.

In the majority of instances the distinguished authors of these reports were able to attend the Congress and initiate discussion of their subject, and the subsequent discussions, both verbal and written, in the various sessions, indicated that the subjects had been given thorough consideration, and the results of the discussions cannot fail to be of great technical and practical value to all interested in the work of the Association, in addition to providing fruitful fields for further investigations.

The four main groups upon which the Association's activities are concentrated include metals, non-metallic inorganic materials, organic materials, and questions of general importance. In the group on metals five subjects had been selected, including the progress of metallography, material at high temperatures, cast iron, fatigue, and notched-bar impact tests, and the session at which these were discussed opened with Dr. W. Rosenhain as chairman.

Progress of Metallography.

In the examination of the constitutional and crystalline structure of metals and alloys the value of metallography has become increasingly appreciated, largely as a result of developments in microscopy and the increased knowledge of its application. Microscopy—the examination of metals and alloys—is now indispensable for ascertaining the crystalline state of a material and changes in the general structure due to varying mechanical and thermal treatment; it facilitates the differentiation of the various constituents of which alloys are built; the detection of non-metallic inclusions is made possible; flaws, blowholes, cracks, and other mechanical defects are shown; small quantities of impurities in metal, which form eutectics around the crystalline structure, become discernible; and the effect of various stresses on structure are readily examined.

Reports on the advances in microscopy and metallography were prepared by Mr. F. F. Lucas, of the Bell Telephone Laboratories, and Dr. J. L. Haughton, of the National Physical Laboratory. These gave statements of the developments in microscopy and metallography since the Amsterdam Congress. Predictions previously made have only been partially realised, but some unexpected developments have occurred, particularly the metallographic applications of the ultra-violet microscope. New equipment for high-power metallography, developed in co-operation with the scientific staff of the Zeiss works, is briefly discussed by Mr. Lucas, who had hoped to give a description of the apparatus. Tests indicate that it will be possible to produce crisp, brilliant images at twice present limits; the order of resolution will be improved, and better optical and mechanical means will be available. The value of the microscope was discussed in its application to the transition constituents in hardened steel, and researches in this important field were summarised. Developments in technique and resolution have shown that minute cracks are present in the martensitic needles of hardened steel. They may not be more than twenty-five atom diameters in width and a thousand in length, but it is suggested that if they are present in a steel part subjected to reversed cycles of stresses, each little crack becomes potentially the starting-point for a fatigue failure.

X-Ray Investigation of the Constitution of Alloys.

Another method of identifying alloy phases is rapidly being developed, by means of X-ray analysis, and although much remains to be done before it can be considered as experimentally fully developed, even at its present stage, it can provide an insight into the structure of alloys which was unattainable by the earlier metallographic methods. Professor A. Westgren, of Stockholm, emphasised the value of X-ray analysis, and suggested that the new procedure is more reliable than thermal analysis and metal microscopy as a means of establishing the real character of the alloy phases, the chemical nature of which has always been difficult to define.

X-ray analysis is also valuable as a means of solving the primary task to which investigators in the field of alloy research nowadays more than ever seem to have devoted themselves—*i.e.*, to establish in detail the equilibrium conditions of alloy systems. So far, only a comparatively small part of the vast multitude of metallic systems have been subjected to X-ray analysis, and that part of chemistry which embraces the compound metallic substances, on the whole, still retains its character of unbroken ground. Present knowledge regarding the laws which govern the combining of metal atoms into compound phases is very incomplete. Some of their features have, however, been brought to light by this new research method, and it is likely that continued X-ray investigations of alloy systems will ultimately provide a very much deepened knowledge regarding these problems.

Recent Developments in Research on the Constitution of Alloys.

The factors that have led to the reconstruction of nearly all equilibrium diagrams were discussed by Dr. W. Guertler, of Berlin. Amongst these factors he included the X-ray research; the elucidation of the magnetic transformation points; the relation between the formation of solid solutions and the type of space lattice; the determination of the influence of temperature on the saturation point of solid solutions of low concentration, a factor which has become important by the discovery of quenchable alloys. Further, the possible presence of several states within one and the same phase, and, finally, certain changes of the space lattice varying with temperature. A compilation is given of some of the most outstanding researches of binary

alloys which have led to marked alterations of the equilibrium diagrams.

Materials at High Temperatures.

Although the use of materials at temperatures above normal is not a new development, the increasing use of high steam pressure, during recent years, has given rise to a large number of problems which depend for their solution on a complete knowledge of the properties of materials at high temperatures. The subject is a very comprehensive one, because of the increased severity of the demands made upon the materials of construction. Reports on various aspects of the subject were submitted by Dr. J. Galibourg, Messrs. R. G. Batson and H. J. Tapsell, and Dr.-Ing. A. Pomp and Dr.-Ing. W. Enders which led to considerable discussion.

The study of the strength of metals at a high temperature raises in the first place the theoretical question as to the existence of a true elastic limit at all temperatures. Experience tends to point to the non-existence of such a limit. The same question also arises as to the existence of a limit towards which flow would tend to occur under a given load, and the same answer can be applied. It is stated that the strength of the metal at a given temperature and under a given load can only be defined by the parameters of the flow-time curve; many investigators, however, endeavour to determine a limiting stress below which at a given temperature breakage will not occur. In practice a simplification is introduced by defining the limits, taking into account the sensitiveness of the recording apparatus. Dr. Galibourg, in his laboratory, determines especially the limit at which the first signs of flow appear ascertainable by means of the Marten's mirror elasticity meter, which has a sensitiveness of one-thousandth of a millimetre. The first permanent sets, when produced, are arrived at in two hours. A new apparatus for determining the creep limit of steel is described by Dr. Pomp and Dr. Enders.

Cast Iron.

The importance of international collaboration in regard to the testing of cast iron was indicated by the number of reports dealing with the subject. Such authorities as Mr. J. G. Pearce, Dr.-Ing. E. Dübi, Mons. A. Porteviu, Professor Dr.-Ing. E. Piwowarsky, and Professor F. Pisek contributed the results of numerous tests on cast iron. The principles determining the choice of methods and conditions of application of tests on materials were discussed as well as the principles governing the determination of the method of testing, the selection of test pieces, and the form and dimensions of the pieces. The application of these principles in their relation to castings was considered, taking into account the intended use of the material, its specific properties, the mechanism of rupture, its homogeneity, defects in the castings, uniformity of manufacture, conditions and cost of machining, the dimensions of the pieces and the fineness of the structure. Improvements in the methods of testing castings were reviewed, including hardness, bending, and shear tests on specimens, the modifications made in testing machines, the use of the modulus of elasticity as a characteristic of castings, the precautions in machining test pieces for shear, and the comparability of the results obtained by various methods of testing.

Fatigue.

Rapid advances have been made in fatigue testing, and a session allocated to the discussion of this subject. Reports were submitted by Dr.-Ing. P. Ludwik, Dr. W. J. Gough, Dr. D. J. McAdam, jr., Dr.-Ing. P. Forcella, Dr.-Ing. E. Schulz, and Dr.-Ing. H. Buckholtz, who considered the subject from many points of view. The term fatigue is a very wide and general definition of a type of fracture brought about by repeatedly overstressing material which is a component part of some structure intended to give long service. Materials are occasionally put into service which, owing to some unforeseen circumstances, are subjected to stresses that exceed their power of resistance. In such cases some crystal of the metal, which happens to be lying in the most highly stressed region, cleaves, or possibly a number are broken more or less in line. Once this occurs the conditions from which failure by fatigue arises has been initiated and it is only a question of time before failure occurs. The ruptured crystal leads to a crack, which becomes gradually greater under stress, until the amount of sound metal remaining is unable to withstand the load imposed upon it and complete fracture occurs.

It is generally recognised that the phenomenon known as fatigue is purely mechanical, depending on a number of circumstances, and while it is possible to subject material to various tests to obtain comparative resistance to stresses applied in numerous ways, there is, apparently, no test that can be applied to demonstrate how the individual crystals, lying in the path of the fatigue crack, failed. A wide range of tests have been included in the reports, and the discussion will certainly assist in elucidating many of the problems associated with this interesting phenomenon.

Notched-bar Impact Test.

It was recognised many years ago that the tensile test did not give all the information about a material that a designer should know. Occasions arose when materials which had successfully passed the ordinary tensile failed in practice in a manner which could not be attributed to errors of design. In order to obtain further information about a material, brittleness tests were devised in which notched test-pieces were broken by a single blow in impact, and the energy of fracture obtained from the loss of energy of the striker. Many different tests have been carried out, but international agreement in regard to the size of test-pieces used has not yet been attained. It is with this object that the problems associated with notched-bar impact tests have been selected for discussion at this meeting, and on which Dr.-Ing. M. Moser, Professor R. Zoja, Dr.-Ing. M. Schmidt, Dr. R. H. Greaves, and Professor A. Steccanella presented reports.

The present situation in Germany with regard to this test is characterised by final elucidation of its practical value, and by investigations tending towards the adoption of a smaller test-piece that would lend itself to more general application than the present standard test-piece. A test-piece recommended for adoption as a German standard is of square section with a round notch 0·078 in. in diameter and 0·118 in. deep. Another test specimen of similar dimensions, but having a triangular notch, is suggested for tough steels. Professor Zoja described a new method in which the deformation of the test-piece is produced in the same apparatus as that used for the measurement of its brittleness. From a comparison of the various results presented the possibility of international agreement should be further advanced.

Relations between Elasticity and Plasticity, Toughness and Brittleness.

At the present time there is considerable difference of opinion in regard to the true significance of terms relating to the properties of materials, and it was considered desirable to have expressions of opinion with the object of reaching agreement when dealing with the bearing of corresponding terms. Reports on this matter were presented by Professor M. Ros and Ing. A. Eichinger, Professor P. Regnauld, Dr.-Ing. G. Sachs, Professor F. B. Seely, and Professor A. Schob. The matter was considered in detail to show the influence of stress and many examples were quoted. It was suggested that the relations can be established between the four properties, taking them in pairs; that the properties of elasticity and plasticity can be measured on tension diagrams from tension results on ordinary test-bars, while differentiation between the properties of toughness and brittleness can be obtained from tests on notched bars. The correct application of the terms and their true meaning is not universally agreed upon, although the difficulties are appreciated.

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CONFIDENCE RESTORED.

IN our August issue we urged the need for rapid action in deciding what sacrifices were necessary to effect economic security in order to put an end to a policy of drift which would otherwise more seriously affect British credit and further restrict industrial enterprise and employment. The recent crisis from which Great Britain is emerging indicates how urgent was the need. It was emphasised that immediate action was necessary because of her disastrous trade position and the increasing costs of her unemployment commitments.

An examination of trade returns month by month will show that the difference between the value of imports and exports has been gradually increasing until it has almost exceeded the value of the exports, a difference which had to be made up in some way. Under normal conditions of trade the value of imports and exports are more than balanced by shipping, banking, insurance and other services, as well as by the returns on overseas investments. Under present industrial conditions, however, the difference is so great that these services and interests have been insufficient to provide a balance, and it has been necessary to borrow.

New fields of development have been discovered for the Polarisation Microscope, by Dr. M. v. Schwarz, of Munich, and October "Metallurgia" will contain a long report of its application in the investigation of copper and aluminium. This report has been prepared by Dr. Schwarz from results of his recent original research work. It will be profusely illustrated, many being faithful reproductions from natural colour slides arranged in collaboration with Dr. W. Rosenhain.

Normally, Great Britain's credit is strong enough to enable her to borrow readily enough, but additional factors had arisen which had created a certain want of confidence. The continuance of the trade depression, for instance, has had an adverse effect on the revenue expectations, and it has been recognised that these would not be fulfilled; yet the expenditure, particularly in regard to unemployment insurance and the dole, has been gradually increasing. Thus the prospect of an adverse balance in the Budget created uneasiness and tended to undermine the whole economic structure. It indicated the possibility of deflation and currency depreciation, which rendered the sterling less stable. The experiences of Austria, Germany, and France were visualised, and it was feared that Great Britain would collapse to a greater extent because the cost of unemployment relief increased as her trade became more depressed, and thus was less able to bear the cost.

The primary object in forming a National Government was to define the steps to be taken to ensure economic security, and the course taken has, for the time being, stabilised the country's currency. Great Britain's currency has always been associated with sterling based on the value of gold. This method provides a safeguard against inflation and links up the country's standard value with that of other countries trading on a gold standard. It is obvious that to attempt the alternative of going off the gold standard would have caused a rapid fall in the value of the £. The fall would have been greater than any figure justified by the comparative purchasing power of sterling and the other currencies, because such a change from the gold standard would have implied panic, and, under such conditions, sales are not restrained by rational calculations. The influence of a fall in the value of sterling would be incalculable; it would inflict a shattering blow to credit throughout the world, and might so shake confidence that credit generally would come into disrepute and banks in every country be subjected to a run.

In view of Great Britain's position as the world's banker the responsibilities of the new Government were tremendous. To have gone off the gold standard would have had serious consequences on our own positions, and the shock to confidence would certainly have placed a further check on business and aggravated the prevailing industrial depression. Depending on exports, as we do, this country stood to lose heavily from anything that dislocated trade or upset the free movements of commerce. Any collapse of sterling would not only immediately increase the cost to us of all our imports, but want of confidence in our ability to meet our obligations in regard to imports might seriously interfere with the desire to trade with us. It was imperative therefore that whatever action the Government took the dangers of inflation could not readily be ignored.

Fortunately the need for alarm has passed. The Government, with the utmost courage, has taken steps to discharge its task of saving the national finance. It has faced facts, and as a preliminary measure has given attention to squaring the Budget. This is a necessity, not only for our own self-respect but for the world's reassurance, and although opinions in this country may differ in regard to the method adopted in balancing the Budget, everyone appreciates that the matter has been tackled in a wholehearted way and considerable relief is felt in commercial and trade circles. Open credits have now been established in America and France which the British Treasury may use, if necessary, to support sterling, and although these credits are only available for a year they will provide a guarantee against any immediate drain on the Bank of England's stock of gold and give time for resuscitation. In view of recent events the importance attached to the maintenance of confidence in sterling, as a world-trade medium, in other countries, has been plainly shown, and it is particularly gratifying that negotiations for this credit have been carried through with the utmost cordiality.

It is not possible to say to what extent the assistance thus rendered will achieve its object. The restoration of soundness and stability to our national finances, with which the resuscitation of our export trade and the re-employment of our idle millions is intimately bound up, may be long and difficult, and many problems have yet to be tackled, but the feeling of confidence now prevailing is a happy augury for the immediate future, and will have a considerable influence in giving that impetus to industry which it so much needs.

FARADAY'S RESEARCHES.

ALTHOUGH Faraday was relatively a poor man, his remarkable ingenuity rapidly gained for him a foremost place amongst the scientific workers of the nineteenth century. The son of a blacksmith, he was born in London on September 22, 1791. After a short apprenticeship with a bookbinder, he became assistant to Sir Humphrey Davy at the Royal Institution, commencing in March, 1813. About ten years later he became director of the laboratory, and in 1833 he was made Fullerian professor of the Institution for life.

The earliest work of Faraday was in the field of chemistry, and was concerned with chlorine, two new combinations of which he discovered. He followed this up by initiating the study of the liquification of gases, from which has resulted the refrigerating industry. In 1825 he isolated benzene when studying coal-tar, and although at that time it was only recognised as a laboratory curiosity, the coal-tar dye industry may be said to be based upon his researches. In addition, he discovered new kinds of optical glass; but his greatest achievements were due to his investigations in electricity.

His discovery in 1831 that an electric current is set up in a wire if it is moved in a magnetic field, has made possible the generation of electric power, through the electric dynamo, on which all modern developments of electricity depend. It is because of this discovery of electro-magnetic induction that special celebrations are being held in London this month to commemorate the centenary of Michael Faraday's great work to the electrical industry.

This great discovery followed a series of electrical discoveries. Thus, for instance, Volta, an Italian, discovered in 1800 a means of producing a continuous current by means of his voltaic pile. Later, in 1819, Oersted observed that when wire conveying an electric current was placed lengthways over a compass needle it caused the needle to turn aside. This disclosed a relationship between electricity and magnetism, the principle of which was worked out in detail by Ampere, a leading French investigator. Oersted's discovery of electro-magnetic force, and Ampere's investigation of the mathematical laws of the mechanical action between electric currents, were known to Faraday when he began his experimental researches into these subjects. In 1821 Faraday found that a wire along which passed an electric current could be kept in continuous rotation round a magnet, and that a magnet would also rotate about a wire. It was not until ten years later that he made the great discovery by means of which the production of electric current from the expenditure of mechanical energy became possible. Thus, instead of using metal plates and chemical solutions in voltaic piles and cells, it was only necessary to set a magnet in motion adjacent to a properly arranged wire coil and a supply of electricity became available.

This discovery of the induced electric current was but the prelude to further progress in the field of electrical research. In 1833 Faraday proved the identity of electricity from different sources; in 1834 came the discovery of equivalents in electro-chemical decomposition; in 1838 electro-static induction, followed the same year by the announcement of the relation between electric and magnetic forces; diamagnetism and the magnetic condition of all matter, and subsequently atmospheric magnetism. Undoubtedly one of the most brilliant scientific investigators ever known, Faraday must be given credit for the solid foundation of electric science as it is known to-day.

While Faraday's researches were chiefly concerned with investigations in the science of electricity, his systematic investigation of steel alloys is frequently forgotten, yet, with Stodart, from 1819 to 1824, he carried out a number of experimental investigations with the object of improving steel. During these experiments such elements as platinum, nickel, chromium, silver and rhodium were used in the making of alloy steels. Specimens of these steels are in the possession of the Royal Institution. His work in this direction was far in advance of his time, as it is only during comparatively recent years that special alloy steels, similar to those he studied, have been developed.

It can certainly be said with truth that the discoveries of Faraday have left an indelible mark on the progress of mankind, for to-day his suggestions in many fields of investigation are still being followed, and results are being obtained in accordance with his brilliant predictions. Small wonder that many scientific associations are meeting in his honour and to commemorate his centenary.

Forthcoming Meetings

BRITISH ASSOCIATION.

Sept. 23–30.—Centenary meeting in London. Papers to be read before various sections include:—
- Notes on a Research on Faraday's "Steels and Alloys," by Sir Robert Hadfield, Bart.
- "Metals and Alloys in Relation to Engineering Progress," by Dr. W. Rosenhain.
- "Wages, Prices, and Employment," by Professor J. H. Jones.
- "The Effect of Temperature on Some of the Physical Properties of Metals," by Professor F. C. Lea.
- "The Photographic Analysis of Explosion Flames," by Professor W. A. Bone.
- A Discussion on Geographical Methods of Prospecting, by eight speakers.
- "A Symposium of the British Fuel Problem."
- "The New Gas Industry," by Sir David Milne-Watson.

THE IRON AND STEEL INSTITUTE.

Autumn meeting at Royal Metal Exchange, Swansea, President, Col. Sir Charles Wright, Bt., K.B.E., C.B. The following papers will be submitted:—

Sept. 29.
- "The Constitution of Iron-tin Alloys," by C. A. Edwards, F.R.S., and A. Preece.
- "The Diffusion of Tin into Iron with Special Reference to the Formation of Columnar Crystals," by C. O. Bannister and W. D. Jones.
- "The Effect of Molybdenum on Medium Carbon Steels Containing 1 to 2·5% of Manganese," by G. Burns.
- "The Influence of Silicon on Nickel Steel," by R. Harrison.

Sept. 30.
- "Mottled Tinplates," by J. C. Jones.
- "Equilibrium of Certain Non-metallic Systems," Part I, by J. H. Andrew, W. R. Maddocks, and D. Howat. Part II., by J. H. Andrew, W. R. Maddocks, and E. A. Fowler.
- "Alloys of Iron Research. Part X.—The Chromium-Iron Constitutional Diagram," by F. Adcock.
- "The Effect of Surface Conditions Produced by Heat-treatment on the Fatigue Resistance of Steel Springs," by G. A. Hankins and M. L. Becker.
- "The Solidification and Crystallisation of Steel Ingots: The Influence of the Casting Temperature and the Under-cooling Capacity of the Steel," by B. Matuschka.

Oct. 1.
- "Production Economy in Iron and Steel Works. Part II.—Costs of Production," by O. Cromberg.
- "The Surface Hardening by Nitrogen of Special Aluminium-Chromium-Molybdenum Steels on a Production Basis," by W. H. Cunningham and J. S. Ashbury.
- "The Structure of Nodular Troostite," by N. T. Belaiew.
- "A Critical Study of the Origin of the Banded Structure of a Hot-worked Hypo-eutectoid Steel," by F. C. Thompson and R. Willows.

Oct. 6. Joint Meeting with Lincolnshire Iron and Steel Institute at Scunthorpe.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND.

Oct. 9. "James Watt" Dinner at Grosvenor Restaurant, Glasgow.

PRESENT-DAY SHIP PROPULSION.

NO one is more fitted to discuss modern shipbuilding and marine engineering than Mr. F. E. Rebbeck, managing director of Messrs. Harland and Wolff, Ltd., who delivered his presidential address before the Institute of Marine Engineers on September 8. His views on the subject are of more than passing interest, in view of the slack condition of the industry, and some of the salient points are given in the following :—

At the present time, he said, there is an enormous tonnage laid up throughout the world, and the opinion is sometimes expressed that there will be little new tonnage constructed until all of this laid-up tonnage is in service. But some is so old that it is now out of date in many respects, possessing insufficient speed to meet modern requirements, poor equipment for handling cargo, propelling installations that are veritable fuel eaters, and generally unsuitable to go on the high seas and compete with modern tonnage. With so much tonnage laid up, and practically no building proceeding in this country, it is a serious thought that foreign countries are steadily building very modern ships which will be a real menace not only to the laid-up tonnage, when it comes once more into the open, but to new tonnage not equally modern.

This means that new tonnage will be required when trade begins to move ; not because there are no ships available in this country, but because much more economical vessels will require to be used to compete with the modern tonnage of our foreign competitors. Rapid developments have been made during recent years, and the subject of ship propulsion has become one of intense controversy. Certainly it must be very difficult for shipowners to satisfy themselves on what is best to be done with any new tonnage they have under consideration in readiness for the day when new orders will have to be placed. While the whole ship will require detailed consideration—for considerable advances have been made in matters of detail in all directions,—the main anxiety will naturally be associated with the system of propulsion that is to be adopted if the best commercial results are to be obtained.

For our purposes the mercantile tonnage of the world may be classified, roughly, into, say, five groups—viz. : (1) The tramp cargo vessel, say, about 10 knots ; (2) the liner type of cargo vessel, say, about 12–15 knots ; (3) the combined cargo and passenger vessel, say, about 16–18 knots ; (4) the medium size, moderately fast passenger vessel, say, about 19–23 knots ; (5) the large fast passenger vessel, up to the largest constructed, say, about 25 knots and upwards.

For the first group the general consensus of opinion amongst British shipowners would call for simple triple-expansion engines with two or more cylindrical boilers, with the minimum amount of auxiliary equipment. The steam reciprocator at present preferred in this country for tramp tonnage is very simple in construction, and very cheap in first cost, two factors of prime importance ; but decisions regarding questions of policy do not permit of the matter being settled in this way.

Not many vessels are included in the fifth group ; consequently the consideration that has to be given to the propelling equipment of these large fast vessels is generally confined to few owners and few builders. The consensus of opinion for this class of vessel is unquestionably in favour of high-pressure high-temperature steam installations, consisting of water-tube boilers and geared turbines with every conceivable refinement which would make for increased economy. To realise the maximum the electric generating units should be driven by oil engines.

For the vessels included in the three middle groups, (2), (3), and (4), which together constitute such a large proportion of the world's tonnage, any well-recognised system of propulsion is technically practicable ; and the problem facing the shipowner is to decide what is commercially best for him in his own individual circumstances. Full consideration has to take into account the first cost, weight, space, insurance, depreciation, operating cost, upkeep, etc. ; and it is only after a very careful examination of all these factors that an answer can be given to the question of what is the best commercial proposition for any particular ship or service. The problem calls for expert judgment, the result of wide and long experience, as what may be suitable for one particular service may be out of place for another. A complicating factor for the shipowner is the conscious or unconscious bias of each engineer whom he consults. The consequence is that the values assigned to the various factors are liable to be so very different, and the conclusions deduced are in their turn extraordinarily divergent. It is here that the shipowner naturally becomes perplexed. The people best able to say which system of propulsion pays them best should be the shipowners themselves, providing their judgment is founded on actual running experience of a number of comparable vessels fitted with the different types of machinery, over a representative period of time—the longer the better—and when all the factors have been brought into the balance-sheet on which their decision is based.

The question of first cost generally settles itself, as far as the owner is concerned, by means of a tender. As regards what the machinery will do in service, the tender only applies to the extent that promises can be considered as acceptable ; and it is in this connection that the question of co-operation between builders and owners comes in.

It must not be inferred that there has been no collaboration in the past. On the contrary, the degree of co-operation between shipowners and shipbuilders has been as close as anything to be found in other spheres of industrial activity. During the last decade there has been the need of closer co-operation between the builder and owner, and the present stagnation in trade has emphasised the necessity of this co-operation being developed to an extent that was not felt to be necessary in the days when this country built and owned by far the greater proportion of the world's shipping. With Great Britain's percentage falling, as it is, this closer co-operation between British shipowners and British shipbuilders is not only desirable but vital.

In considering the possibilities associated with marine engineering developments, Mr. Rebbeck stressed the necessity for patience and for the continuation of co-operation after any new kind of machinery has been placed in service. The engineers responsible for any phase of development, or for the design and manufacture of any type of machinery, should have the fullest information, over a reasonable period of time, regarding its performance.

In considering the fuel problem, Mr. Rebbeck stated that investigations in connection with the use of pulverised coal, and, more important still, research into the subject of oil extraction from coal along the lines of the hydrogenation process, while receiving a considerable amount of attention, must be given more vigorous support if sufficiently rapid progress is to be made to reduce the present menace to our coal-fields. The application of oil fuel has made such progress that there seems no prospect of recalling success to the coal-fields unless the hydrogenation process, or something equivalent, is developed in different centres of the country on a very big scale. The phenomenal progress that it has made with the internal-combustion engine has not been the result of its popularity, but rather its inherent capacity for producing low running costs. It had to contend with the fact that it was an expensive machine to produce, and was therefore handicapped by a high first cost. But it has now reached the stage of development where its cost on a horsepower basis is very materially reduced.

The proper and natural place for each of the different systems of propulsion will in due course be determined by the extent to which in the passing years they can meet owners' service requirements to the best advantage, but the science of ship propulsion is progressing in so many different directions simultaneously that it is advisable to keep an open mind for any development, in whatever direction it may take place.

Correspondence.

PROGRESS OF ARC WELDING.

The Editor, METALLURGIA.

Dear Sir,—We have read with a great deal of interest Mr. Lacy's article on "The Progress of Arc Welding," as published in the July issue of METALLURGIA. We are particularly interested in his comments on corrosion.

There is no question but that welds heretofore (at least those made with the bare or lightly-coated electrode) have been subject to corrosion to a greater extent than the parent metal when subjected to acid conditions, and while results formerly were as recorded by Mr. Lacy, yet, due to recent developments in the welding art, the question of corrosion has been entirely eliminated.

Developments of the shielded arc in the last several years, as exemplified by the heavily-coated electrodes such as "Fleetweld," and by the automatic type of welder such as the "Electronic Tornado," have not only eliminated the question of corrosion, but introduced several other very important advances in the art of arc welding.

Fig. 1.—The effects of corrosion on weld metal produced by an unshielded arc (upper weld) and shielded-arc weld metal (lower weld).

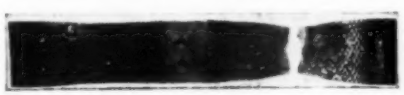

Fig. 2.—The cross-sectional area of weld (produced by shielded arc) in this test bar was reduced below that of the plate metal, which broke as shown at 54,000 lb.

Fig. 3.—A test bar cut from 2-in. plate welded by shielded arc. Specified tensile strength of plate was 70,000—75,000 lb. per sq. in. When pulled it broke at considerable distance from the weld at 74,300 lb. per sq. in. tension.

The effect of corrosion on the weld metal and the parent metal is an important factor which should be given serious consideration in the determination of the method or process of arc welding to employ, especially in the manufacture of products which would be subjected to acid fumes, weather conditions, or buried in the ground. The rate of deterioration as a result of corrosion is often an influencing factor in the sale of an arc-welded product which, in its use, is subjected to the causes of corrosion.

The effects of corrosion on welds made with shielded and unshielded arcs can be easily ascertained after a 72-hour immersion of the welds in a 50% solution of hydrochloric acid. The welds (Fig. 1) were subjected to this particular corrosion test. Close inspection of this illustration reveals that although the weld produced by the shielded arc is not affected, the acid has eaten rather deeply into the weld metal deposited by the unshielded arc. The corrosion of this weld is due to the presence of foreign material, which is mostly iron oxide, in the weld metal. The other weld, having been made with a shielded arc, which prevented inclusion of oxides and nitrides in the weld metal, was thus able to resist corrosion to a far greater degree.

For many applications, however, corrosion is not the deciding factor, even more important being tensile strength and ductility.

Since the strength and ductility of welds are dependent on the purity of the weld metal and the nature of metallic structure, it is obvious that welds produced by an unshielded arc cannot possess the physical characteristics of

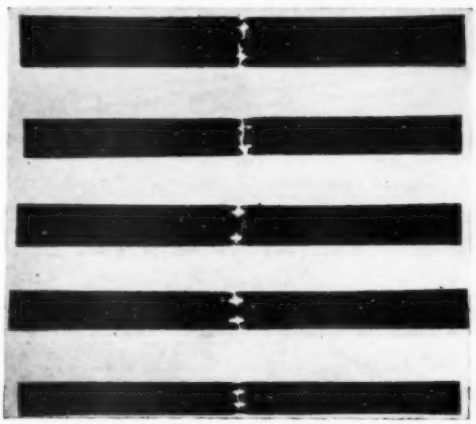

Fig. 4.—Five test bars cut from steel plates welded by shielded-arc process. Welds machined flush with plate and holes of $\frac{1}{8}$-in. diameter drilled through weld to ensure failure of weld. The top test bar was welded by student after one day's training in use of shielded-arc process. The remaining four test bars were welded by commercial operators in four different plants, none of which had been using the shielded-arc process more than one month.

welds made in a shielded arc. Hundreds of tests have proven that welds under stress fail at that point where the oxide and nitride content is greatest. The degree of brittleness of a weld is also largely due to the amount of oxides and nitrides contained in the weld metal.

Welds produced in a shielded arc show a tensile strength of 60,000 lb. to 75,000 lb. per sq. in.—10,000 lb. to 20,000 lb. per sq. in. greater than rolled steel. An example of the strength of welds made in a shielded arc is shown by the test-bar (Fig. 2) formed by butt-welding two pieces of

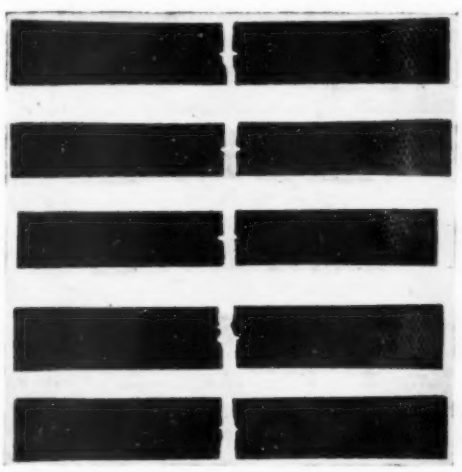

Fig. 5.—Test bars from steel plates welded by bare or washed electrodes. Welds were machined flush with plate and $\frac{1}{8}$-in. diameter hole drilled to ensure weld failure. These test bars were submitted by five industrial concerns as examples of their best welding with unshielded arcs.

mild rolled steel plate by the Lincoln "Fleetweld" process. Before testing this bar, the weld was machined flush with the plates, and the cross-sectional area of the weld metal reduced below that of the plate metal by drilling two 0·182 in. diameter holes through the weld. The test-bar broke in the plate metal under a stress of 54,000 lb. per sq. in. The weld showed no sign of failure even though it was subjected to a stress of 60,900 lb. per sq. in.

The thickness of the material welded has no effect on the tensile strength of welds made by the shielded arc. For instance, note the test-bar (Fig. 3) cut from welded 2-in. plate. This test-bar was pulled until failure, which occurred in the plate as shown.

Hundreds of tension specimens have been cut across welded joints made by the shielded arc, and on test the

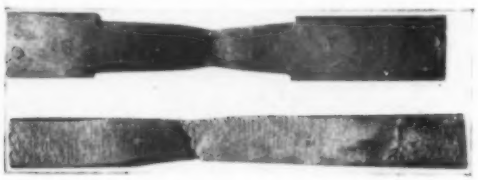

Fig. 6.—Test bars composed entirely of weld metal produced by the shielded-arc process. These bars are two of hundreds which have been pulled to determine elongation of weld metal. The elongation in 2 in. for the upper bar was 27%; for the lower bar, 21%.

failure has always occurred in the plate, even though the sectional area of weld metal had been reduced to that of the plate by machining the weld flush with plate. Failure has been made to occur in the weld by drilling holes in the weld metal to increase the stress per square inch on the weld under test. Compare the results of tests on tensile specimens welded with a shielded arc (Fig. 4) and specimens welded by ordinary arc (Fig. 5), as given :—

	Ultimate Tensile Strength, Lb. per Sq. In.		
	Min.	Max.	Average.
Shielded arc weld metal (see Fig. 4)	65,600 ..	75,100 ..	70,350
Ordinary arc weld metal (see Fig. 5)	42,700 ..	56,100 ..	49,400
Plate metal	55,000 to 65,000		

In most applications of arc welding high ductility of the welds is as essential as high tensile strength. A weld of good tensile strength may not be ductile; however, welds produced in a shielded arc possess both characteristics in a high degree. For instance, the results of the test (Fig. 2) demonstrate not only the high tensile strength, but also the ductility of the weld metal. In this test the holes drilled through the weld metal before testing were 0·182 in.

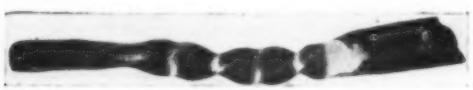

Fig. 9.—This test bar composed only of shielded-arc weld metal was twisted cold through 405° without sign of failure.

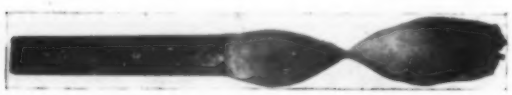

Fig. 10.—Two bars fused together by shielded-arc process and then forged and twisted through 180° without fracture.

in diameter. After the bar was pulled to failure, it was found that this dimension of the holes was increased to 0·266 in. or an elongation of approximately 40%.

The results of tests for elongation of weld metal deposited in a shielded arc (Fig. 6) are given below. Note the great ductility of shielded arc weld metal :—

	Elongation in 2 in.		
Weld Metal.	Min.	Max.	Average.
Shielded arc	18% ..	27% ..	23%
Ordinary arc	8% ..	12% ..	10%
Plate metal	21·5% to 25·4%.		

By bending a standard test specimen to angle of 180°, using the weld as a pivoting point, the outside fibres are elongated an appreciable amount. In the case of the test specimen illustrated (Fig. 7) the elongation of the outside fibres was 43%. Note that no crack appears in the shielded arc weld after this test.

Another simple method which vividly demonstrates the greater ductility of welds made in a shielded arc is to make a weld with a shielded arc on a piece of steel plate, also a weld produced in unshielded arc on the same plate and parallel to the other weld, then bend the plate across the welds until one weld breaks. The results of such a test (Fig. 8) prove the greater ductility of welds made in the shielded arc. Twisting the weld metal will also indicate the high degree of ductility possessed by shielded arc welds. For example, note the bar of shielded arc weld metal (Fig. 9) which has been twisted cold through 405° without fracture.

That welds produced in a shielded arc possess the same ductility as forged steel is demonstrated by welding two parallel square bars together and then forging this steel and twisting it through 180° (Fig. 10). A portion of this test sample was twisted through 360°

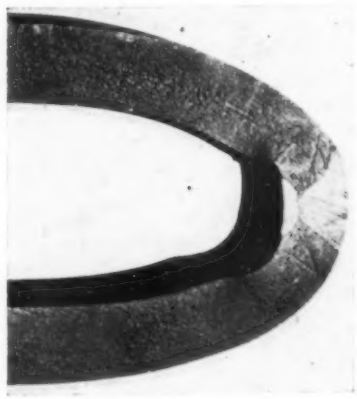

Fig. 7.—A typical specimen of bend test across a shielded-arc weld. Elongation of the outside fibres of the weld metal was 43%. Note that no crack appears at the top of this weld.

In the discussion above no mention has been made of the speed which necessarily affects the cost of welding. This is always a very important factor in the application of any process of welding. It is sufficient perhaps to say that the speed obtained by the use of the shielded arc (using "Fleetweld" electrode) is from two to four times as fast as that obtained by the usual arc-welding methods. In the case of the automatic (electronic tornado) speeds of three to five times as fast are obtained, as compared with the usual hand method.

This means that the slight additional cost of the electrode is more than made up by the reduced labour cost, so that in general it may be said that using the shielded-arc process, and considering labour, material, and current, welding with results previously mentioned can be obtained at materially less cost than with the older methods.

Fig. 8.—Specimen of a simple test which demonstrates the greater ductility of welds produced by shielded-arc process.

Shielded-arc electrode similar to "Fleetweld" is sold in this country at about 15 to 75% more per pound than the bare or lightly-coated electrode, but is only a fraction of the cost of electrodes such as the asbestos-covered type.

The rapid development of this type of welding has made possible, for the first time, the getting of a metal in the weld comparable to the parent metal at an economical cost figure equivalent to the former methods of welding.—Yours very truly,

THE LINCOLN ELECTRIC COMPANY,

A. F. DAVIS, Vice-President.

Aluminium Sheet Production

By Robert J. Anderson, D.Sc.

Part IX.—The Hot Break-down Operation.*

Factors which influence the hot-rolling temperatures: slab thicknesses, drafts and passes, lubrication of ingots and cooling of rolls are discussed.

FROM the production point of view, a high break-down temperature—below the critical hot-shortness temperature corresponding to the maximum draft—is advantageous because the passing may be more drastic—*i.e.*, the operation may be carried out faster. On the other hand, certain operating difficulties are concurrent with high rolling temperatures. Thus, it is more troublesome to hold the slab dimensions (width and thickness) precisely with increasing temperatures. Breakage of ingots, particularly on the first pass, is more frequent at the higher temperatures, and the slabs are more prone to be "fire-cracked."† Higher ingot temperatures cause higher roll temperatures and, consequently, lessened life of rolls, particularly in the case of chilled cast-iron rolls because of fire-cracking and breakage. As affecting the quality of the resultant product and the scrap losses at the inspection bench, it is of interest to point out that the tendency of aluminium sheet to blister on anneal is much lessened by using an extraordinarily high break-down temperature for the ingots.

The disadvantageous effects of a too-low hot-rolling temperatures are reflected in lessened production and possible damage to the mills. If the ingots are relatively cold the drafts must be lighter, consequently more passes must be taken, and the time of operation is longer. Too-heavy draft on a relatively cold ingot may fracture a coupling, cause crushing of the breaker block, or stall the motor. The finishing temperature or temperature of the slab on the last pass is, of course intimately related to the original temperature of the ingot, the number of passes, and the method of cooling the rolls. Ordinarily, the finishing temperature is about at, or a little below, the nominal recrystallisation temperature. When aluminium ingots are broken down at about 450° C. the slabs come off the mill at, say, 315° to 340° C. Hot-mill slabs may have scleroscope hardness of about 8 (magnifier hammer), indicating some hardening by cold work; unworked or fully annealed aluminium has scleroscope hardness of about 5.

As is obvious, hot-rolling temperatures can be controlled more precisely and satisfactorily when ingots are pre-heated (or soaked in an equalisation furnace) then when rolled directly from the moulds. Practice in the melting room necessarily influences rolling temperatures in the latter case. Thus, in the production of ingots for wide sheet, the pouring temperature may be held appreciably lower than when ingots for coil rolling are cast. Hence, wide-sheet ingots will arrive at the hot-mill feed table at a lower temperature than coil ingots.

It goes without saying that uniformity in temperature of successive ingots is highly conducive to smooth and fast operation at the hot mill. Hence, pre-heating or equalising is indicated. Of course, serious inequalities in temperature may be compensated by the hot roller with suitable alteration of the drafts and passes. Preferably, the hot roller should know the temperature of the ingots. In some plants it is practice for the hot roller to measure the temperature of each ingot as delivered to the mill. If the ingots are coming over too hot, or too cold, suitable adjustment of conditions may be made at the mould line-up (when rolling directly from the moulds), or at the pre-heating furnace. Variations in composition of metal, which are bound to occur in practice, and which affect performance at the hot mill, can be quickly detected by the hot roller. Small change in the break-down temperature, one way or the other, may promote better rolling behaviour without resort to alteration of the drafting.

Fig. 3 shows a surface contact pyrometer which may be used in measuring the temperature of aluminium rolling ingots.

Thickness of the Hot-mill Slabs.

In the hot break-down operation aluminium and alloy ingots are rolled to slabs of nominal thickness in the range 0·2 in. to 0·5 in. Slab thicknesses are usually specified, on the break-down order sheet, precisely as 0·250 in., 0·375 in., or 0·400 in., indicating close tolerance. It is, of course, neither necessary nor practical to attempt to hold the slab thickness within close limits; rolling to ±0·005 in. is regarded as very good, and variation of ±0·01 in. is good enough for most purposes. Uniformity of slab thickness is, however, desirable from the point of view of the subsequent rolling operations. In practice, slab thickness should be varied according to the sheet product which is to be rolled, the final gauge being the governing factor. Other factors affecting slab thickness include the width of the sheet, the temper, details of the cold rolling, and intermediate anneals (if any). These items are inter-related.

As indicating the influence of the finished gauge on the original slab thickness, in aluminium practice, it is generally considered advisable that the cold reduction in area prior to final anneal should be held within narrow limits. The control of cold reduction is especially important in the production of deep-drawing stock, where the percentage should correspond to the critical stress for minimum grain size (on annealing). Unfortunately, the control of slab thickness with reference to the percentage of cold reduction to finished gauge is often not given the attention it deserves, with the result that inferior sheet is produced. More will be said in a later article about the control of cold reduction and its effects.

As a practical matter in hot rolling, slab thickness may be governed to some extent by the size of the required slab and the weight of the ingot. Thus, where it is desired to control the width and length for some reason, the thickness must be varied to suit. Ordinarily, however, the ingot is rolled to width and thickness, and the length is allowed to run. Some idea of the thicknesses rolled in practice for different gauges may be gained from the following:—

In one mill all ingots going into flat-sheet production, where the break-down product is slabbed, are rolled to ¼ in. thick on the hot mill. In another plant, where the hot-mill slabs are processed in a continuous mill, all ingots for flat-sheet production are hot rolled to ⅜ in. thick; ingots for strip and coil sheet to finish over 28 in. wide are hot rolled to 0·3 in., and under 28 in. to ⅜ in. In another mill ingots for flat-sheet rolling were hot rolled to ¼ in. for sheet to finish 16-gauge (Brown and Sharpe) and heavier, and to 0·3 in. for sheet lighter than 16-gauge. In the same plant it was practice to roll ingots for coil production to ⅜ in. for material less than 20 in. wide, and to ¼ in. for material more than 20 in. wide. In still another mill ingots for flat-sheet production were hot rolled to the thicknesses indicated in Table I, which shows the variations

† The cracks and fissures caused by rolling at too high a temperature are not to be confused with the impressions formed on slab surfaces by fire-cracked rolls.

* *Continued from page* 118, *August issue.*

with gauge and size. As a general rule, the hot-mill slab should be of such thickness that it may be reduced 50 to 75% in cross-sectional area by cold slabbing and leave sufficient thickness for roughing and finishing. Slabs for sheet (plate) to finish $\frac{1}{8}$ in. thick and heavier are often hot rolled to within 0·1 in. to 0·2 in. of the final gauge, the variations depending on the thickness.

As a general rule in hot rolling the slab thickness should be so varied (within reasonable limits) as to produce an area which will yield the minimum losses on shearing. As will be evident, if slabs of various widths are rolled to the same nominal thickness for use in producing sheet and coil of various sizes, then the shearing losses may be minimum in some cases, but greater than minimum or even maximum in other cases. It is naturally more troublesome to plan the production where the attempt is made to closely control shearing losses by varying the slab thickness. Also, as a practical matter, it is less troublesome to roll to a nominal thickness (*e.g.*, 0·3 in.) than to produce slabs of odd and precise thickness (*e.g.*, 0·279 in.).

If the hot-mill rolls are badly fire-cracked,† slabs may be rolled thicker than otherwise, so as to allow extra metal for working out the impressions put on the surfaces by such rolls.

The widths to which slabs are hot rolled are governed by the shearing allowances, and whether the material is rolled in multiple widths for splits. In general, the lighter the gauge the greater the finish shearing allowance (both sides and ends). This matter will be dealt with at length in a later article of this series when considering the planning of production. After rolling to width on the earlier passes, the spread on rolling to thickness is small, so that slabs may be readily produced in the desired widths and thicknesses.

TABLE I.

THICKNESSES TO WHICH INGOTS ARE BROKEN DOWN HOT FOR VARIOUS SIZES AND GAUGES OF ALUMINIUM SHEET.

Finished Gauge, B. and S. No.	Finished Width, In.	Finished Length, In.	Thickness of the Hot-mill Slab, In.	Remarks.
1–4	*	*	0.500	Finished from the hot-mill slab.
5–7	*	*	0.300	Finished from the hot-mill slab.
8–9	*	*	0.250	Finished from the hot-mill slab.
10–11	*	*	0.200	Finished from the hot-mill slab.
12–13	*	*	0.300	Slabbed cold
14	40	124	0.300	Slabbed cold
14	40–70	125–160	0.400	Slabbed cold
15	*	*	0.250	Slabbed cold
16	40	100	0.250	Slabbed cold
16	48	124	0.300	Slabbed cold
16	60	160	0.400	Slabbed cold
17–25	*	*	0.250	Slabbed cold
Lighter than 25	*	*	0.200	Slabbed cold

* Indicates practically any length or width.

NOTE.—In general, hot-mill slabs for sheet production are slabbed cold to one-half the original thickness.

Details of the Passing.

Practice at the hot mill in rolling aluminium slabs of various sizes does not lend itself well to explanation without detailed description and numerous examples. In the present article the underlying principles are dealt with briefly, methods of determining roll sets are described, and typical passing charts are shown in tabular form. It will be understood that the possible variations of drafting and passing are almost limitless, and will necessarily vary, depending upon the composition rolled.

Drafts in Hot Rolling.—Fast practice at the hot mill calls for few passes and heavy drafts. Other things being equal, there is a certain minimum number of passes for satisfactory results in any break-down operation; if fewer passes are used the slab tends to roll out of square, curl up, stick, or be off gauge. Much has been said about light versus heavy drafts in both hot and cold rolling. A good rule to follow in aluminium practice is to break the ingots down as rapidly as possible, consistent with the production of satisfactory slabs. The advantages of heavy reductions are faster operation and possibly more dense and homogeneous metal. Practice in drafting varies in different plants, depending on the past experience or preferences of the operators. There are no definite standard methods used throughout the aluminium-rolling industry.

At one mill, in hot rolling 99+% metal the first two passes are very heavy, the reductions being upwards of 40% or more each; on succeeding passes the reductions are progressively diminished, being decreased to about 20% on the last pass. In another mill the first couple of passes carry reductions of about 35% each; on the next few passes the reductions are about 18–20%; the final passes reduce the area about 30% each. It is to be understodd that in cross-rolling for width the reductions are varied to suit the conditions; one heavy, one light, or two moderate reductions, for example, may be required in rolling to width. The reductions on cross-rolling are not considered in the examples just given.

In another plant the first pass is rather light so the roller can "feel" (obtain an idea of the rolling characteristics of) the ingot. It may be said, parenthetically, that with proper technical control of operations there is no necessity for a light first pass or reliance on the hot-roller's judgment as to the drafting. If the required slab is not too wide the ingot is rolled to width on the second pass, the reduction varying with the required extension. Otherwise, the reduction on the second pass may be moderate, and the ingot may be rolled to width on the third or fourth pass.

In rolling wide slabs it is advisable that the pass reductions be reasonably light, otherwise the slab is likely to be distorted out of square. Where the length is extremely disproportionate to the width, it is practically impossible to produce slabs with even approximately square corners.

Table 2 shows the thicknesses of slabs after each of the successive passes in breaking aluminium ingots measuring $4\frac{3}{4}$ in. by 12 in. by 21 in. to $\frac{1}{4}$ in. for widths in the range of 20 in. to 54 in. Additional information regarding drafts is to be had from Tables 3 and 4, which indicate roll sets.

It will be understood that the maximum permissible draft per pass when hot rolling duralumin and other strong alloys is considerably less than when rolling 99+% aluminium and soft alloys. Thus, an alloy ingot $4\frac{3}{4}$ in. thick may be broken to a slab 3 in. thick with five or six passes, then re-heated and rolled to $\frac{3}{8}$ in. thick with about eight to ten passes. In rolling the hard alloys light drafts are necessary, in part because of the tendency to crack. With suitable adjustment of composition and proper pre-heating heavier drafts may be taken. Up to date, the bulk of the production of duralumin and other hard alloy sheet has been made on mills designed for aluminium. More power is required to roll the hard alloys than the 99+% metal, and it is possible that the equipment is underpowered as regards these alloys. Hence, lighter reductions must be made per pass. Some alloys can be reduced only about $\frac{1}{8}$ in. to $\frac{1}{4}$ in. in thickness per hot pass, as compared with upwards of 1 in. for aluminium.

Direction of Rolling.—In starting the passing at the hot mill the ingot may be hit end-on or side-on—*i.e.*, in the case of a $3\frac{1}{4}$ in. by 14 in. by 24 in. ingot either one of the $3\frac{1}{4}$ in. by 14 in. faces or a $3\frac{1}{4}$ in. by 24 in. face will be presented for the first bite. Practice in regard to this matter is different in different mills, and also in the same mill, depending on the size of slab to be rolled (in relation to the dimensions of the ingot). Thus, if an ingot of the size just mentioned is to be rolled to a slab $\frac{3}{8}$ in. thick by 18 in. wide, the ingot may be hit end-on for the first pass, then turned at right angles and cross-rolled to width on

† The cracks and fissures caused by rolling at too high a temperature are not to be confused with the impressions formed on slab surfaces by fire-cracked rolls.

the second pass, and then again turned at right angles and rolled to thickness on the succeeding passes. In some cases, where the desired width of slab exceeds the standard width or length of the ingot somewhat, the ingot may be hit end-on or side-on and rolled directly to thickness, the width being caught by the squash—*i.e.*, the side-spread on the early heavy drafts. Ordinarily, however, the ingot is rolled to width with one or more passes.

Some operators claim that rolling in the direction in which the ingot was cast (referring here to ingots poured in vertical tilting book-moulds) tends toward sliver formation in the resultant sheet. Thus, it is claimed that if ingots are rolled at 90° to the direction in which poured dross films tend to be rolled out to the sides, which latter are subsequently removed by shearing. On the other hand, when rolled lengthwise, such inclusions are disseminated throughout the mass of the slab. Of course, it is not often possible to roll in the direction desired because of the necessity of cross-rolling for width, or for some other reason.

During the break-down operation the metal tends to flow backward from the direction of rolling. If the successive passes are largely in the same direction (as in the case where the rolling is done on two-high irreversible mills, the slab being returned over the top roll, and not turned 180°), the back end of slab tends to be harder and thinner than the front end. This is, of course, undesirable. Uniformity of thickness from end to end can be obtained by normal operation on a two-high reversible mill; on the ordinary two-high mill the slab should be turned 180° per pass. This latter practice naturally reduces the speed of operation.

Cross-rolling.—As is obvious, it is neither practical nor necessary to cast ingots in a widely varying range of widths suitably corresponding to all widths of slabs which it is desired to roll. Accordingly, where the width (or length) of the standard ingot does not correspond to the width of slab required, allowance being made for side-spread—this being the normal situation—cross-rolling must be done. It is sometimes claimed that cross-rolling yields inferior quality of metal. This is undoubtedly fanciful, since practice has been developed requiring as much cross-rolling as possible from the ingot to the finished sheet for the purpose of improving the material. Cross-rolling probably yields a more uniform slab structure than rolling only in one direction. In any case, it is a practical necessity, and is carried out mainly to play for width. The direction of cross-rolling may be regarded as the direction of passing in rolling to width—this being at 90° with the other passes. Or, it may be considered as the direction in which the fewest passes are taken, which usually amounts to the same thing.

Ingots (or partly broken slabs) may be hit corner-on. This has the effect of extending both the width and length. It may also be done, on a light pass, for the purpose of squaring corners. If the slab, particularly when wide, tends to finish wider at the middle than at the ends the difficulty may be offset by rolling longer on the second straight pass (*vide* Table 2); if it tends to finish narrow at the middle the slab may be rolled shorter on that pass.

Roll Opening and Slab Thickness.—The relation between the roll opening and the slab thickness on any hot pass depends upon various factors, of which the most important are: (1) The play or looseness in the mill, particularly the bearings and screw-downs; (2) the temperature of the ingot (slab); (3) the draft; and (4) the number of the pass.

Increased play in the mill increases the slab thickness—*i.e.*, the amount by which the thickness exceeds the roll set. Undue variation can be eliminated by proper conditioning and maintenance of the mill. The slab thickness more closely approaches the roll set with higher rolling temperatures since the resistance to flattening is less. By the time the later passes are taken the metal has cooled considerably, some hardening has set in, and the resistance to deformation is greater; consequently, the variation between roll set and slab thickness is greater the thinner the slab. Fast rolling and sufficiently high finishing temperatures are, accordingly, indicated. When heavy drafts are taken on the first couple of passes the ingot squashes out at the sides more or less so that the width increases. This increase is reasonably constant for given thickness of ingot, given temperatures, and drafts, so that allowance may be made for it. For given conditions the greater the draft the more the variation in slab thickness—excess over the roll set. This follows because of the increased pressure which tends to spring the rolls apart.

There are also certain peculiarities of mill conditions, ingot sizes, and drafting which affect the variation. These need not be considered here.

The difference between the actual reduction in thickness and the draft as indicated by the roll set may vary from about 0·1 in. to 0·4 in., the amount depending on the temperature of the slab, the number of the pass, whether the pass is straight or cross, and other factors.

The Dial Sets.—Irrespective of the type, the aluminium hot mill is normally equipped with a suitable dial-and-pointer arrangement which indicates the opening between the rolls. This opening is referred to as the roll set. In two-high aluminium hot mills of any type the position of the lower roll is fixed, and vertical movement of the upper roll is accomplished by motor drive through screws, the dial (or pointer) revolving with the screws. The pitch of the screws may be such that one revolution of the dial corresponds to a vertical movement of 1·000 in. of the upper roll. If the dial is divided into 50 equal parts, one part equals 0·02 in. movement of the roll. The pitch may be finer if desired, and the size of the dial may be increased so that divisions equal to $\frac{1}{100}$ of the circumference may be read with accuracy.

TABLE II.

THICKNESSES OF ALUMINIUM SLABS AFTER EACH OF THE SUCCESSIVE PASSES ON HOT ROLLING.

Finished Width of Slab, In.	Number and Direction of Pass. First, S.*	Second, S.	Third, C.†	Fourth, C.	Fifth, S.	Sixth, S.	Seventh S.	Eighth, S.	Ninth, S.
	Thickness of Slab after the Pass.								
20	3¼	2⅜	1⅜	1 13/32					
21	3¼	2⅜	1⅜	1⅜					
22	3¼	2⅜	1⅜	1 11/32					
23	3¼	2⅜	1⅜	1 5/16					
24	3¼	2⅜	1⅜	1 9/32					
25	3¼	2⅜	1⅜	1¼					
26	3¼	2⅜	1⅜	1 7/32					
27	3¼	2⅜	1⅜	1⅜	1 ⅛ C				
28	3¼	2⅜	1⅜	1⅜	1 3/32				
29	3¼	2⅜	1⅜	1⅜	1				
30	3¼	2⅜	1⅜	1⅜	⅞				
31	3¼	2⅜	1⅜	1⅜	⅞				
32	3¼	2⅜	1⅜	1⅜	⅞				
33	3¼	2⅜	1⅜	1⅜	⅞				
34	3¼	2⅜	1⅜	1⅜	⅞				
35	3¼	2⅜	1⅜	1	⅞				
36	3¼	2⅜	1⅜	1	⅞				
37	3¼	2⅜	1⅜	1	⅞				
38	3¼	2⅜	1⅜	1	⅞				
39	3¼	2⅜	1⅜	1	⅞				
40	3¼	2⅜	1⅜	1	⅞				
41	3¼	2⅜	1⅜	1	⅞				
42	3¼	2⅜	1⅜	1	⅞				
43	3¼	2⅜	1⅜	1	⅞				
44	3¼	2⅜	1⅜	1	⅞				
45	3¼	2⅜	1⅜	1	⅞				
46	3¼	2⅜	1⅜	1	⅞				
47	3¼	2⅜	1⅜	1	⅞	⅞ C			
48	3¼	2⅜	1⅜	1	⅞	⅞ C			
49	3¼	2⅜	1⅜	1	⅞	⅞ C			
50	3¼	2⅜	1⅜	1	⅞	⅞ C			
51	3¼	2⅜	1⅜	1	⅞	⅞ C			
52	3¼	2⅜	1⅜	1	⅞	⅞ C			
53	3¼	2⅜	1⅜	1	⅞ C	⅞ C			
54	3¼	2⅜	1⅜	1	⅞ C	⅞ C			

* S, Straight Pass. † C, Cross Pass.

NOTE.—The above applies to ingots measuring 4¼ in. by 12 in. by 21 in. to 24 in.

‡In the case of ingots measuring 4¼ in. by 12 in. by 16 in. to 20 in., the thicknesses of the partly broken slabs are the same as shown except on the second straight pass, where the slab is reduced to 2¾ in. thick instead of 2⅞ in.

(To be continued.)

Machinability with Shallow Cuts

CONSIDERABLE study has been made during recent years on the performance of lathe-tools with both roughing and shallow cuts. Particularly is this true of the U.S. Bureau of Standards, which has recently published a report by Mr. T. G. Diggis of a series of tests carried out with the object of determining the performance of lathe-tools with shallow cut as affected by variations in chemical composition and heat-treatment of steels cut. The cutting tests described were made dry, with high-speed steel tools of a selected size, form, composition, and heat-treatment, with a feed of 0·0115 in. per revolution and 0·010 in. depth of cut. Comparisons were made of the Taylor speeds on the basis of equal tensile strengths when cutting 0·4% carbon, chromium-vanadium, nickel-chromium, chromium-molybdenum, and 3½% nickel steel forgings heat-treated to give tensile strengths between 75,000 and 220,000 lb. per sq. in.

Although most attention was given to tool life with shallow cuts in studying the machinability of the different forgings cut in the lathe tests, it was also recognised that the structure and appearance of the surface finish are important factors in finishing cuts, and possibly may be considered as factors in any index to machinability. Further, in view of the fact that high-speed steel tools containing considerable proportions of cobalt have been reported to give excellent performance when cutting hard metals and to have made possible the commercial machining of high manganese steel, the tests with shallow cuts were extended to include the cutting of nickel-chromium forgings. Thus, this study includes a consideration of the surface finishes of the various steel forgings as affected by test conditions, the microstructures of the steels cut, and tool performance as affected by the additions of 3·5 to 11·7% cobalt to the customary 18% tungsten type of high-speed steel.

The method used for testing the lathe tools with shallow cuts was based upon the fact that when two tools are set in equal depths in one tool-holder the second, or indicating tool, will not cut so long as the leading, or test tool, shows no wear. With this method of test, the indicating tool began to cut when the wear on the test tool was from 0·001 to 0·002 in., and this was considered as the point of failure of the test tool. In most cases it was found that the wear of 0·001 to 0·002 coincided with a complete breakdown of the tool comparable to that found with heavy cuts in rough turning.

Measurable and consistent differences were observed in the machinability of the carbon and alloy steels used. The fact, however, that some given steel permits a higher cutting speed than another steel for some tensile strength which is the same for both materials, does not necessarily indicate that the two steels maintain the same relationship for another tensile strength. The 0·4% plain carbon steel, within the range of tensile strengths obtained by heat-treatments, was the most difficult to machine with shallow cuts other than an annealed nickel-chromium steel. The surface finishes of the carbon steel forgings were also inferior to those produced on the alloy steel forgings. An exception was found with a particular heat-treatment of the plain carbon steel, showing a microstructure of partially spheroidized or agglomerated cementite, on which a medium smooth and satisfactory finish was obtained with the cutting condition used. This same heat-treatment also resulted in the best machinability of the group of the carbon steels when comparisons were made on the basis of the cutting speeds at equal tensile strengths.

As a result of these tests it is concluded that the superiority in cutting speeds of the alloy steels over the plain carbon type is not to be attributed solely to any single alloying element, but rather to the combined effects of the alloying elements present in any particular steel, considering carbon also as one of the alloying additions.

Further, the effect of changes in chemical composition of steel forgings upon their cutting speeds is dependent not only upon the tensile strength at which comparisons are made, but also upon the conditions of cutting. That is, steel forgings that show superior machinability with shallow cuts at some tensile strength do not necessarily show a similar superiority with roughing cuts.

Elements which cause a lowering in the cutting speeds of the annealed steels may improve the cutting speeds when considering higher tensile strengths. It was shown that of the special elements that improved machinability of the different steels cut with shallow cuts, the most effective were the combinations of nickel and chromium or chromium and vanadium for the higher tensile strengths, in the neighbourhood of 180,000 lb./in.², and chromium and molybdenum in the lower range of tensile strengths, about 90,000 lb./in².

In general, the cutting speeds were not appreciably affected by the method of heat-treatment by which a given tensile strength was produced. The cutting speeds were slightly higher with the higher tempering temperature when comparisons were made of different methods of quenching and tempering to produce approximately equal tensile strengths. In two steels, namely, with the plain carbon steel and 3½% nickel steel, the better machinability was produced by the heat-treatment consisting of quenching and subsequently tempering at a high temperature than with the annealing treatments used.

Lathe-tool performance with shallow cuts was improved by the additions of cobalt (together with higher hardening temperatures) to the customary 18% tungsten type of high-speed tool steel. The maximum gain in performance was shown when cutting the forgings with tensile strengths up to about 170,000 lb./in.², but above this strength the gain in performance was not so marked. Previous test results were confirmed in that the increase in cobalt above about 5% did not produce improvements in tool performance of the same order as those resulting from 3½ to 5% and higher hardening temperatures.

The differences observed in the surface finish of the different types of alloy steel forgings were not large, and all were considered as being of about equivalent smoothness. For the cutting conditions investigated, the chromium-vanadium, chromium-molybdenum, nickel-chromium, and 3½% nickel-steel forgings were considered as producing surfaces of approximately equivalent smoothness, and were slightly superior to the nickel-chromium steel. There were, however, no very marked differences observed in the appearance of the surfaces of the forgings of the different alloy compositions and all could be classified as satisfactory. Each type of alloy steel showed surfaces that were considered much superior to that of the plain carbon steel. The characteristic finish of the different alloy steels may be described as smooth, medium, to highly polished, with but little tearing and showing some tool marks.

The microstructures and surface finishes of all the alloy steel forgings with the varying heat-treatments were examined, but no correlation between structure, surface finish, and machinability appeared possible, but a correlation of the cutting speeds, tool life, surface finish, etc., shows that, with the test method used, the machinability of the carbon and different alloy steel forgings used in the experiments may be properly determined or measured by the cutting speed, permitting the tool to last a definite time.

The Low-frequency Induction Furnace and Its Scope

By A. G. Robiette, B.Sc.

Improvements in lining methods have made possible the melting and superheating of cast iron, the melting of high-copper alloys, nickel brasses, and cupro-nickel alloys.

PROBABLY the greatest development in the history of the wrought-brass industry has been brought about in recent years by the introduction of induction melting, and, in particular, by the almost universal adoption of the vertical-ring type of furnace.

The reasons for this revolution in melting practice are not far to seek when due consideration is given to the unique characteristics of this type of furnace. Perhaps these are best described by tracing the development of this system of heating from its beginnings in the horizontal-ring furnaces of 30 years ago, and by examining the features of this new system in conjunction with the particular requirements of brass melting.

The operating principle of all low-frequency induction furnaces* is that of a simple, static, step-down transformer,

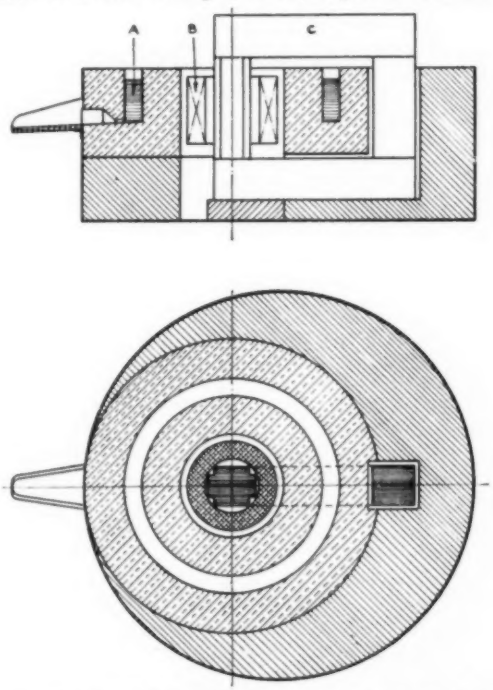

Fig. 1.—Horizontal ring-type low-frequency induction furnace.
(A) *Molten metal.* (B) *Primary coil.* (C) *Iron core.*

the secondary being the loop or ring of metal to be melted. The essential difference is one of objective—in the transformer the heat generated in the secondary is a source of loss, while in the induction furnace it is utilised. In this respect the induction furnace may be looked upon as a combination of an air-cooled transformer and a direct-resistance furnace.

The early horizontal ring or open-channel type of furnace was the outcome of the researches of Ferranti in England, and Colby in America, and was subsequently developed by Kjellin, Frick, Rodenhauser, and others. The various modifications of this furnace differ only in detail, and Fig. 1 illustrates a representative design.

* *Note.*—The "normal-frequency" furnace would be the more correct term, but "low-frequency" furnace is used in this connection in contradistinction to "high frequency" or "coreless induction" furnace.

It is obvious from the diagram that this furnace must offer a large area for magnetic leakage, as the primary winding and the secondary channel are so widely separated. The furnace will, therefore, suffer from an inherently low power factor. This, of course, varies with the size of the furnace and the thickness of refractory material. The larger the furnace, the looser is the electromagnetic coupling and the lower the power factor. There are, however, other conditions besides these which affect the the power factor adversely. The power factor will be given by the following equation :—

$$\text{Cos } \theta = \frac{R}{\sqrt{R^2 + W^2L}}$$

where R = ohmic resistance,
L = coefficient of mutual inductance,
W = $2\pi \times$ frequency = angular velocity.

So that, other things being equal, the power factor will be lower as the resistance decreases. The power factor will therefore depend upon the nature of the charge to be melted, and also on the cross-sectional area of the metal bath—*i.e.*, on the weight of metal charged. G. E. Taylor* cites an example showing how the quantity of metal charged influences both the power and the load factor.

A furnace charged to half capacity gives the following electrical characteristics :—

R $\times$ 0·000544 ohms
Cos θ = 0·88
Power taken = 143 kw.
K.V.A. = 162

When the ring is filled :—

R = 0·000272 ohms
Cos θ = 0·68
Power taken = 170 kw.
K.V.A. = 250

This furnace must have a completed secondary in order to set it in operation, so that either a quantity of molten metal or a specially cast starting ring, having the shape of the hearth, must be employed. The rest of the charge is subsequently fed into the channel.

From the above considerations it is evident that at the commencement a smaller amount of power is required, and it is not permissible to increase the current beyond a certain limit in order to avoid rupturing the circuit owing to a phenomenon known as the "pinch effect," which is explained later. Full load cannot, therefore, be accommodated until the later stages of the heat, so that the load factor is consequently low.

When larger installations are contemplated, either the circumference of the ring must be increased or the cross-section of the channel made larger. The former condition entails a looser electromagnetic coupling, while the latter reduces the ohmic resistance; thus both make for a low power factor. In order to counterbalance this, the frequency has to be lowered in accordance with the above equation. Such low periodicities as 15—10 cycles have, therefore, to be used for furnaces having capacities of 10—15 tons. This necessitates the use of abnormally large generators, which are inadmissible for ordinary works requirements owing to their abnormal periodicity.

* *Electrical Review*, August 21 and 28, 1925.

Besides these electrical difficulties, the shape and disposition of the hearth introduces many metallurgical disadvantages. It has a large area of refractory material in proportion to its capacity, with high maintenance costs. The wear on the lining is also aggravated by a circulatory motion in the channel owing to the fact that the current density varies over the cross-sectional area, the inside of the ring having less resistance than the longer outside path. Moreover, this awkward shape of the bath is difficult to insulate, and the slag is always cold, so that it is inefficient as a refining appliance—in short, it foundered on "a rock of inconvenience."

In spite of its obvious shortcomings, the pioneers of this method of induction heating were so imbued with the idea that this was theoretically the correct method of melting metals, that they spent much time and money in the pursuit of their ideal. Their fruitless efforts in perfecting this type of furnace brought to light, however, many facts concerning the behaviour of liquid metallic conductors, and it was not until the significance of these was fully realised that the horizontal ring furnace was abandoned. In the meantime the arc furnace was introduced in this country in 1909, and was found to be a more efficient refining appliance. This retarded the development of the induction furnace in ferrous melting practice, but in the non-ferrous industry progress was proceeding along different lines.

Fig. 2.—Attractive forces between parallel conductors carrying currents in the same direction.

Attempts had been made to melt copper alloys in the open-ring type of furnace, but the manifestation of the "pinch effect" caused the rupturing of the metal in the secondary channel. This was due to the fact that the ohmic resistance of these high-copper alloys was low as compared with steel, consequently producing a high current density. The American Brass Co. carried out experiments in a furnace of this type on the melting of brass, but these were also attended by failure, due to the volatilisation of zinc and the above effect causing the breaking of the secondary circuit.

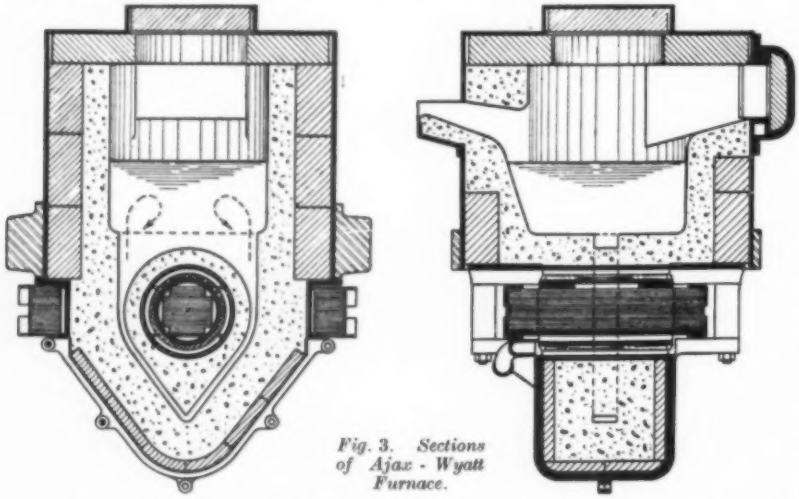

Fig. 3. Sections of Ajax - Wyatt Furnace.

It is fitting at this stage to obtain a clear conception of the "pinch" phenomenon, which plays so important a part in the design of low-frequency induction furnaces. It is commonly known that parallel conductors carrying currents in the same direction attract each other, and with a force which is proportional to the product of the intensity of these currents. Fig. 2 illustrates a diagram showing this effect.

Now it is feasible to regard a molten metal as consisting of an infinite number of parallel conductors free to move. Therefore, when a current flows, a radial pressure will be exerted on the liquid and will operate much in the same manner as if the metal were "pinched" at a point and "squirted out" at the ends. If this constricting force is so great that metal is forced away from the point faster than it can return, the circuit will be interrupted.

This was first observed by Hering,* who noted that deep depressions occurred on the surface of a molten metallic conductor when the current density reached a limiting value. He even went so far as to utilise this effect to produce circulation in a furnace heated by electrodes. Although his experiments were unsuccessful, he did blaze the trail for his successors, who were to give the world one of the most useful and efficient types of electric furnaces.

To prevent the rupturing of the secondary ring of metal by the "pinch effect," a simple method suggested itself to C. P. Schneider—namely, to apply a longitudinal pressure in the channel, which would counteract the radial pressure due to the attraction of the hypothetical current-carrying elements. This he did by designing a submerged channel furnace, in which the overlying pool of metal exerted a hydraulic pressure on the metal in the secondary pool. The idea was admirably conceived, but difficulties arose in the execution, due to the fact that the circulation of metal was too sluggish to transfer the heat generated in the channel to the bath above. Overheating resulted, with consequent refractory failures, and, moreover, when melting brass violent volatilisation of the zinc occurred in the secondary loop.

Experiments were simultaneously proceeding in America with a view to discovering a method of increasing rate of removal of the metal from the submerged channel. This was attained by Wyatt, who found that in V-shaped channels an electrodynamic force acts, which he called the "motor effect." This is caused by the condition arising due to the currents flowing in different directions in the limbs of the V channel. Conductors carrying currents in opposite directions will tend to repel one another, so that if these conductors meet in the shape of a V and are free to move, as with a liquid, the metal will tend to be forced to the position where it is furthermost from the junction—*i.e.*, to the overlying pool. This force will be greatest at the apex of the V, where the limbs are in contact, while the "pinch effect" will manifest itself to its greatest extent at the junction of the V channel with the metal bath. To aid further this circulatory action there is the effect of convection, which arises due to the difference in density between the heated metal in the channel and the cold metal above. The combined effect of these three forces produces an intense circulatory motion, the extent of which may be gauged by ascertaining the requisite rate of change of metal in the secondary loop, to prevent volatilisation of zinc, due to overheating (G. E. Taylor).†

The V channel contains approximately 21 lb. of metal (in a 600-lb. furnace). The number of units required to heat this from 950° C. (melting point) to 1,150° C. (the temperature at which zinc volatilises in the brass) is 0·285, so that if the furnace is developing 74 kw. the rate of change of metal in the channel must be at least 3·5 times per minute, to avoid volatilisation of zinc.

In this way was developed the vertical submerged-channel-induction furnace of to-day, commonly known as the Ajax-Wyatt furnace. Fig. 3 shows two sections through the furnace.

Its success was established in the melting of brass containing up to 70% copper, and even a cursory

* Hering. Trans. Amer. Electrochem. Soc. vol. ii. and vol. xv. † *Loc. cit.*

examination of the peculiar requirements of brass melting will emphasise its eminent suitability for this operation.

One of the most important considerations in brass melting is a consequence of the high vapour pressure of zinc at the pouring temperature—namely, the loss of zinc during melting. The curve, Fig. 4, reproduced from a paper by Gillett and Mack*, on "Brass Furnace Practice," shows the narrow margin existing between the pouring temperature of copper-zinc alloys and the temperature at which rapid volatilisation of zinc commences. It is imperative that a close control over the input of energy and the temperature of melt should be maintained to avoid excessive volatilisation of zinc. Besides being a source of considerable financial loss, and physical discomfort to the furnace operatives, the loss of zinc prevents a check on the composition of the charge being kept. This is a serious consideration, as it is generally not practicable to make sample analyses as in steel-melting practice. In methods of melting which have a temperature gradient as the means of heat transfer, this fine control is difficult, due mainly to the fact that the container and other refractory parts are at a higher temperature than the actual melt, so that even when the supply of heat is discontinued, the temperature of the metal will still continue to rise, owing to the higher temperature and the large heat content of the crucible and refractory material. This is not only eliminated in the induction furnace, but the fact that the hottest part of the system is the submerged channel enables an indication of the correct pouring temperature to be obtained in a novel manner. Volatilisation of zinc will start first in the secondary channel, and this will cause the circuit immediately to be interrupted, with consequent visible fluctuation of the ammeter needle. This is a very useful feature, and serves to dispense with other forms of temperature-indicating devices. Prevention of zinc loss is further aided in the induction furnace by the ability to seal the metal chamber atmosphere, which need be disturbed only for charging, and, moreover, by the absence of a flow of furnace gases over the surface of the melt, as in reverberatory furnace practice.

Another difficulty in brass melting arises from the tendency to gravitational segregation in certain alloys, especially those containing metals insoluble in the liquid state, such as lead. This necessitates mechanical stirring of the metal to ensure the uniform distribution of the alloying element. Iron rods are usually employed for this purpose in pit-fire practice, but this method, besides being incomplete and tedious, involves the danger of contamination with iron. The continuous circulation (the intensity of which is brought out in the above example of the change of metal in the submerged slot) is of immense advantage in this connection and removes the difficulty entirely.

There are other factors, such as unequal temperature distribution, the effect of impurities in furnace gases, etc., which are of considerable moment in the selection of a heating medium for brass melting, but these are too self-evident to need emphasis here.

Recent researches have brought out, however, a fact which is too often lost sight of—namely, the extreme porosity of refractory materials to furnace gases at high temperatures, and the deleterious effect of furnace gases on the soundness of copper and copper-alloy castings.

The results of an investigation recently carried out under the auspices of the British Non-ferrous Metals Research Association by Prytherch, Allen and Daniels† prove that the unsoundness in copper and bronze castings is a direct consequence of the melting conditions. Hydrogen and sulphur dioxide, which are always present in furnace gases, are mainly responsible for the unsoundness, and their effect is aggravated by the presence of oxygen. In the case of hydrogen, which is always present in cathode copper, the oxygen reacts with this constituent during the freezing of the metal, so forming blowholes; while sulphur dioxide behaves in accordance with the following equation:

$$SO_2 + 6\,Cu \longleftrightarrows Cu_2S + 2\,Cu_2O.$$

So that if oxygen and sulphur are simultaneously present, blowholes containing SO_2 will be formed. Close control over the atmosphere is therefore imperative, and the true remedy obviously lies in eliminating furnace gases, to which refractory containers are so permeable. In short, it is not too rash an inference to be drawn from this work, that for the production of high-quality castings and ingots the melting of copper and copper alloys in fuel-fired furnaces will be superseded in the near future by electric melting.

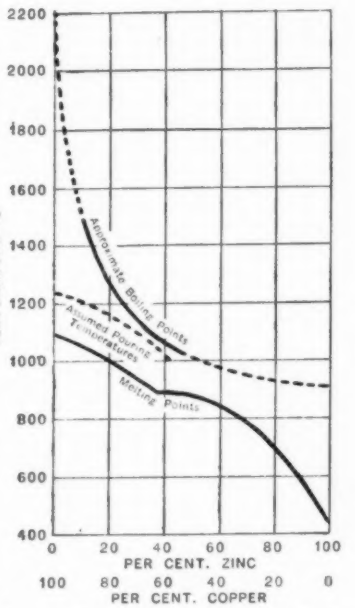

Fig. 4.—Temperature Curves for Cu-Zn Alloys.

With regard to the most economic size of furnace, this has previously been discussed by D. F. Campbell* and M. Tama,† and the conclusion reached is that it depends upon operating conditions, the most important being the size of ingot to be cast. The three sizes which have been constructed hold 300 lb., 600 lb., 1,200 lb. and 2,400 lb., and require respectively 40, 60, 120, and 240 k.w. (The melting time is approximately one hour in each case). The largest unit has the advantage of higher efficiency, and to some extent lower labour costs—the power consumption in a 1,200-lb. unit being approximately 10% less than for the 600-lb. furnace.

For the casting of small ingots of 100—160 lb. in weight, what would be gained by the higher efficiency of the larger unit is lost in the extra time required for pouring. In America, where works are equipped for the cold rolling of brass, the 600-lb. furnace is almost universally in use, but in some European works casting ingots up to 1,200 lb. in weight, and where hot rolling is practised, the larger units of 1,200 lb. and 2,400 lb. capacity have found favour.

Three furnaces of this latter type have recently been installed in this country and are interesting, in that they depart from the original construction which had a single secondary slot. All previous furnaces were consequently single-phase units, but the 240 kw. furnace, which has two inclined secondary channels, is suitable for operation from a two-phase, or—by Scott-connecting the primary coils—from a three-phase supply.

The difficulties of melting brass swarf in the induction furnace, which arises from the bridging and scaffolding of the charge, have also recently been overcome by the use of a charging and poking machine. The swarf is delivered to the furnace on a shaking launder, while the swarf is rammed into the crucible, bringing it into contact with the liquid charge. It has been found that this increases the output by 20—25%. The same result is attained by first briquetting the swarf, using a boric acid flux.

* Bulletin No. 202, U.S. Dept. of the Interior.
† *Journal of the Institute of Metals*, 1930, No. 1.

* *Journal of the Institute of Metals*, 1929, No. 1.
† *Journal of the Institute of Metals*, 1929, No. 2.

(To be continued.)

Reviews of Current Literature.

HIGH-SPEED STEEL.

THE increasing use of high-speed steel has had a considerable influence both on machine-shop practice and design. It has made possible an enormous increase in cutting speeds, feeds, and depths of cut. Its effect was a revelation, and machine makers found it necessary to adjust the design of their machines to the new conditions necessitated by faster and heavier cutting. Even the developments in cutting materials which have produced the tungsten, chromium, and cobalt compositions only tended to intensify progress in the use of high-speed steel. The improvements made in the tool steel were increased when it was found that an increased percentage of tungsten in its composition, after a suitable heat-treatment, produced a quality in the steel that had long been desired—namely, the ability to retain its hardness even after heating up to a dull red. This characteristic of high-speed steel tools, together with their ability to remove a large amount of metal in a short time, can only be obtained by exercising the greatest care in the manufacture of steel of suitable composition, submitting it to the most effective hot-working and heat-treatment.

The subject is discussed very fully in this book, in which the authors present a general view of the manufacture and properties of high-speed steel. They endeavour to show how the behaviour of the high-speed steel in manufacture and in final preparation, is governed by general laws, and how its fundamental properties are precisely responsible for its immediately useful properties. It is this combination of theory and practice that the authors have kept in mind in the preparation of the book..

The work is conveniently divided into two parts, the first dealing with what the authors consider to be good practice in the manufacture, hammering, and rolling of ingots and bars, in heating operations during fabrication, and in the preparation and heat-treatment of the finished tools ; the second gives an account of fundamental physical properties, the constitutional diagrams, the microstructures developed under various conditions of manufacture and heat-treatment, and their correlation with the ultimate mechanical properties. The authors deal primarily with American practice, and though there are slight differences in practice in this country, in principle they are similar. A comparison is made between the crucible and electric furnaces, but only the salient features that apply particularly to high-speed steel are mentioned, and these only briefly. No mention is made of the high-frequency furnace for this type of steel. In regard to the casting of ingots, the authors emphasise the influence of casting temperature and the subsequent cooling of the ingot on the structure, and state that a large ingot cooling more slowly than a smaller ingot will have a coarser carbide structure by comparison. We are, however, not convinced that for a given size of standard bar it is possible to secure a more refined carbide structure by selecting a larger ingot and giving it the extra reduction required. The authors take, for example, a 2-in. square bar, which may be made from a 5-in. square ingot, or from a 10-in. square ingot. The 10-in. ingot will have coarser particles *initially* than the 5-in. ingot, on account of its slower solidification. But in making a 2-in. square bar, a 10-in. ingot is reduced 96%, whereas a 5-in. ingot is reduced only 84%. The greater reduction of the 10-in. ingot, they state, will more than compensate for the somewhat increased size of the original carbide particles, with the result that the bar from the 10-in. ingot will have a finer structure than the one from the 5-in. ingot. Obviously, therefore, the size of the ingot could be increased with further advantage to the structure of the steel. We think, however, there is a limit beyond which it is not safe to cast ingots.

The chapters dealing with cogging and recogging of the ingots, finishing and annealing, are particularly informative, and clearly indicate the amount of care necesary in the various processes to produce high-quality material. It will be appreciated that high technical skill and ability are essential, and slight departures from established practice frequently lead to a scrap product. In the production of the best high-speed steel, it is important to eliminate the large carbide-tungstide skeletons, as carbide out of solution, in any form other than small spheroids, is usually found to be detrimental. In ordinary carbon steels the excess iron carbide is readily soluble by heat-treatment, but in high-speed steels carbide-tungstides, whether present as skeletons, envelopes, or laminations, are almost impossible of solution by heat-treatment alone. The only method for obtaining the desired solution is apparently by forging and rolling in combination with annealing.

The second part of this work, dealing with the nature and properties of high-speed steel, is very comprehensive. An interesting theory is developed with regard to the nature of red-hardness. High-speed steel, they say, is apparently composed of a matrix, hard at elevated temperatures as well as room temperature, which possesses at least traces of plasticity, and of very hard particles distributed within this matrix. The matrix appears to be at the optimum condition when it is as hard as is compatible, by nature, with a slightly yielding plasticity. The hardness refers to a condition existing at about 600° C., otherwise the particles may be depressed under the high surface pressure, and not be presented at the surface to resist abrasion nor offer the requisites for initial penetration at the beginning of the cut. It appears that the matrix should consist of a metal which has been hardened considerably beyond that of the non-brittle pure metals in the composition by one of the familiar metallurgical methods—viz. : solid solution, martensitic hardening, and precipitation hardening, and the authors suggest that the three methods are very intimately related in producing the quality of red-hardness in the steel.

The constitution of high-speed steel is considered as a ternary and as a pseudo-binary alloy, and approximate constitution diagrams are given showing each system, while subsequent chapters deal with metallography of the solidification, working, and heat-treatment of high-speed steel, and illustrate some excellent photomicrographs of the steel under various conditions of manufacture. The functions of the individual alloying elements are discussed, while the magnetic properties of high-speed steel, its density, crystallinity, and the chemical analysis of its constituents conclude a work of more than ordinary interest.

The book is well prepared and produced, and incorporates a useful index. Its 178 pages is full of valuable information on high-speed steel, and all who are associated with the manufacture or use of cutting materials will find in it a useful fund of knowledge in both theory and practice from which they can draw as circumstances require.

By Marcus A. Grossmann and Edgar C. Bain, and published by John Wiley and Sons, Inc., New York, U.S.A., and Messrs. Chapman and Hall, Ltd., 11, Henrietta Street, Covent Garden, London, W.C. 2. Price 17s. 6d. net.

The Institution of Mining and Metallurgy.

THE August Bulletin, No. 325, contains a paper by Mr. L. C. Stuckey on "The Use of Borehole Pumps for Mine Drainage," which is submitted by the Institution for discussion by correspondence in anticipation of discussion at a meeting to be held during the coming session. The author gives details of results obtained in working an installation, consisting of pumps suspended in boreholes, which has been in use for mine drainage for over two years. This issue also contains further correspondence on Mr. M. Scott's paper entitled "The Treatment of Hollinger Precipitate to Produce Fine Gold," and also Mr. G. F. Hatch's paper entitled "Check Sampling of Diamond Drill Holes at the Trepca Mines, Yugoslavia."

The Institute of Metals

Annual Autumn Meeting.

A wide range of metallurgical and engineering problems were discussed at this international gathering of scientists over which Dr. Richard Seligman presided.

THE annual autumn meeting of the Institute of Metals, held at Zürich on September 13–15, by kind invitation of the Schweizenische Verband für Materialprüfung, proved to be very attractive, and the attendance was a compliment to the excellent arrangements made for the comfort and convenience of members and their friends. The initial opening of the meeting, at which the visitors were officially welcomed on behalf of the Schweizenische Verband für Materialprüfung, was held in the Auditorium Maximum of the Eidgenössische Technische Hochschule, where the tenth autumn lecture was subsequently delivered by Mr. Ulick R. Evans, M.A., on "Thin Films on Metals in Relation to Corrosion Problems." The lecture was followed by an informal gathering in the Great Hall, where light refreshments were served.

The general meeting of members was held the following day in the Auditorium of the Eidgenössische Technische Hochschule, and at the conclusion of the necessary business the meeting was converted into a session at which papers presented were briefly summarised and discussed. It is rarely that time permits more than a very brief discussion at meetings of this kind, and this meeting was no exception to the rule, although considerable interest was shown in the subjects under discussion. The arrangements for visits to works during the afternoon received gratifying support; those visited included the large hydro-electric power station about 30 miles from Zürich, which supplies power to the town and the Swiss Federal Railways; Fischer's iron and steel works, and the testing-machine works of Messrs. Alfred J. Amsler and Co., at Schaffhausen; while for those interested in water and steam turbines, compressors, refrigerating machinery and centrifugal pumps, the works of Messrs. Escher, Wyss and Co., of Zürich, were available for inspection.

A technical session was held during the morning of the following day, at which further papers presented were briefly summarised and the subjects discussed, after which the general meeting was formally closed. Members subsequently visited extensive electrical machinery works at Oerlikon and Baden, and also Messrs. Pulzer Brothers at Winterthur, who specialise in internal combustion engines, refrigerating and heating plants, etc.

During the progress of the technical sessions and works visits special arrangements had been made for the ladies, visits being made to the Kunsthaus, an excursion to the Metliberg, while other visits included one to the Landesmuseum. The social arrangements and tours prepared for members and their friends for a few days following the meeting, as well as further visits to the works, combined to make this meeting an interesting one for those interested in metallurgical problems, and it also provided an opportunity for sight-seeing under congenial conditions. In addition to these advantages, however, the association with members and friends of kindred societies on the Continent, having a common object, cannot fail to be of lasting benefit. Such meetings assist in breaking down national barriers and prejudices, and facilitate a better understanding between different peoples which fosters mutual goodwill.

The papers presented at the technical sessions were very comprehensive, covering as they did the results of much research in various sections of the non-ferrous field, as well as dealing with many subjects from a practical point of view. In addition to the autumn lecture by Mr. Evans, about twenty-five papers were presented, and it is only possible to summarise them very briefly here.

THIN FILMS ON METALS IN RELATION TO CORROSION PROBLEMS.

Tenth Autumn Lecture.

Much valuable research work has been devoted to the subject of corrosion, and although considerable progress has been made in combating this waste of material, it is generally acknowledged that much remains to be done. Corrosion prevention is really an economic problem, as it has been computed by Dr. Robert Hatfield that the cost of the corrosion of ferrous metals alone reaches an annual amount of £700,000,000, and with the additional waste of non-ferrous metals from this cause the cost must be enormous. Much work on the fundamental cause of corrosion has been done in regard to metal surface films and potentials, work in which Mr. Evans has participated, particularly in connecting changes of potential with film formation, he has utilised these potential changes in tracing the formation of films, while in previous work he separated these invisible films from the surface of metals. The lecturer is chairman of the Laboratory Corrosion Test Sub-Committee, appointed by the Joint Committee of the Iron and Steel Institute and the National Federation of Iron and Steel Manufacturers, with the object of devising a suitable laboratory test for atmospheric corrosion, and it is particularly appropriate that he should have chosen corrosion problems for his lecture.

The subject of corrosion is a very comprehensive one, but in this lecture the subject was confined to the effect of thin films on the behaviour of metals towards corrosion influences and tarnishing. It has long been known that treatment of a metal with an oxidising agent—although usually producing no change in appearance—often leaves the metal in a curious inert or "passive" condition. This condition has been shown to be due to the formation of an oxide film. It is probable, however, that most of the metals carry oxide on the surface even when they are bright, but in most cases the oxide produced by the action of air is normally pervious to ions and the metals become passive or inert only when the metal is subjected to special treatment, which brings the oxide film in a state of good repair, so that it can prevent leakage.

These ultra-thin oxide films, which render metals passive or relatively immune from corrosion, are usually invisible, as long as they are in optical contact with the brightly reflecting surface, although they are quite visible when removed from it; the slightly thicker films, responsible for interference tints, have usually little protective character. Both types of films have been isolated and studied. Many methods have been devised for isolating the films, and almost all methods depend on some treatment which attacks and removes the metal whilst leaving the oxide unchanged. At Cambridge Mr. Evans and his collaborators have found a concentrated solution of iodine in potassium

iodide of service for isolating the oxide films of iron. A more convenient way is by means of anodic treatment. This method has been used at Cambridge to isolate films from copper and nickel, as well as from pure iron, mild steel, and stainless steel.

These films do not generally give effective protection unless they are self-healing: this self-healing property largely depends on precipitation of some secondary corrosion product very close to the surface. Even where films do not prevent corrosion, they may play a part in deciding the distribution of attack, which takes place preferentially at the places where no healing occurs; where mechanical action keeps breaking the skin or removing corrosion products from any particular point, attack tends to be localised at the point in question.

In concluding his lecture, Mr. Evans stated that "possibly in the near future scientific researches will indicate the manner in which many of the practical problems of corrosion could be solved. But it is to be feared that any success achieved in the researches, however complete, will not in itself prevent the recurrence of corrosion troubles. For chemistry is so much neglected in the engineer's training to-day that the correct application of the results, when obtained, may be deferred indefinitely. The difficulties of forcing an increasing number of new subjects into the curriculum are fully appreciated, but they do not afford a justification for the neglect of chemistry by engineers at a time when chemical problems are assuming—for engineers—a growing importance." A point of view that many engineers are being forced to appreciate.

FIRST TECHNICAL SESSION.

At the first session eight papers were presented covering a wide field of study, and all were open for oral discussion with the exception of two on which discussion will be in writing. Messrs. H. Waterhouse and R. Willows have studied the effects of cold-rolling, heat-treatment, and storage on the Brinell hardness of 14 lead alloys containing small additions of tin, cadmium, and antimony. The hardness numbers of the cast alloys ranged from 5 to 18 Brinell. Their investigations have shown that cold-rolling hardened the soft alloys and softened the hard alloys, the hardness immediately after cold-rolling lying in all cases between 8 and 11 Brinell. Self-annealing at atmospheric temperature further reduced the hardness to about 7 Brinell.

Most of the alloys, especially those containing cadmium and antimony, were re-hardened to approximately the "as cast" hardness by suitable heat-treatment, quenching, and ageing. Certain alloys age-hardened after air-cooling, or even more restrained cooling from the heat-treatment temperature. The age-hardness persists for several months at least, but is destroyed by severe cold-working and self-annealing. The hardness of the harder alloys "as cast" is largely due to age-hardening. An alloy containing 1·5% cadmium and 0·5% antimony is particularly susceptible to age-hardening.

A large field would be opened to the use of magnesium alloys, particularly in aircraft construction, if their tendency to corrode could be overcome. The subject of the protection of these alloys from corrosion is discussed by Messrs. H. Sutton and L. F. Le Brocq, who have examined methods involving chemical treatment of the surface followed by the application of lanolin or a suitable enamel. Two chemical processes which have been developed afford very fair protection—viz., immersion for 6 hours in a bath containing 1·5% potassium dichromate, 1% alum, and 0·5% caustic soda, the bath being maintained at 95° C.; and immersion under the same conditions in a bath containing 1·5% potassium dichromate and 1·5% sodium sulphate (decahydrate). For surfaces which are in the "as cast" condition, a preliminary cleaning treatment in 10% nitric acid is necessary, but for parts machined to fine tolerances this method is too drastic. In such cases a solution of 2% caustic soda is used. Sand-blasting as a preliminary treatment is not recommended.

In order to obtain reliable values for the elastic limit of nickel-copper alloys containing up to 50% of nickel, Messrs. D. G. Jones, L. B. Pfeil, and W. T. Griffiths have investigated these alloys, and in addition determinations have been made of maximum stress, elongation, and reduction in area. It was found that the elastic limit is low in substantially pure nickel-copper alloys in the fully annealed and in the cold-drawn conditions, but that high elastic limits are developed in all compositions as a result of low-temperature heat-treatment following cold-working. High elastic limits may also be produced in nickel-copper alloys containing small amounts of such elements as silicon, which render the alloys susceptible to heat-treatment.

By a combination of the effect of cold-work and low-temperature heat-treatment with the effect of precipitation hardening, high elastic limit material may be produced with greater facility than by either method alone, whilst good combinations of mechanical properties may be developed by suitable compositions and treatment. With higher contents of silicon a certain amount of difficulty is met with in some production operations, but even with less than 0·25% silicon exceptionally good properties can be obtained, and the alloys of this composition present no difficulty in manufacture.

Unsoundness in Aluminium Sand-Castings.

Experiments which have been carried out both in the laboratory and in the large-scale foundry tests for the British Non-Ferrous Metals Research Association have been directed mainly to the determination of methods and conditions under which pinholes may be eliminated from aluminium alloy castings by treatment of the molten alloy prior to casting, and a study of the effects of various gases, including steam, nitrogen, chlorine, and mixtures of nitrogen and chlorine has been made. The incidence of pinholes in castings made from various batches of virgin aluminium ingot is very variable, which seems to point definitely to some inherent quality in the virgin aluminium or stock alloy used, and two papers by Messrs. D. Hanson and I. G. Slater describe investigations on the causes of pinholes and related phenomena in sand castings and the developments of methods for their prevention and elimination.

The authors conclude that water vapour, either in the furnace atmosphere or bubbled into the molten alloy, is found to be very deleterious, rapidly giving rise to extensive pinholing and unsoundness. Treatment with dry nitrogen or chlorine usually effects an improvement in soundness. A mixture in equal proportions of the two gases gives results superior to those obtained by either of the gases used separately or consecutively. The temperature at which the melt is treated is found to be a very important factor, the most satisfactory results being obtained at temperatures just above the melting point of the alloy.

A gas treatment with the chlorine-nitrogen mixture at a temperature of 700° C. or below for a period of 10 mins. will effectively remove all visual pinholing and unsoundness from a 3-lb. melt in the electric furnace, and works-scale experiments agree with those conducted in the laboratory. It has also been found that treatment with volatile constituents such as sulphur, selenium, tellurium, and cadmium has been tried, with varying results. Superheating "2L5" alloy to 950° C., prior to casting at normal temperature greatly reduces the number of pin-holes.

In regard to virgin aluminium, it is found that after exposure to suitable corrosive conditions, and subsequently sand-cast, it is unsound and contains pin-holes. Alloys of aluminium including "3L11," "2L5," "Y" and 12% silicon, show a similar phenomenon. The extent and amount of unsoundness which is produced depends upon the type and time of exposure, and also upon the particular alloy examined. The suggestion is made that the deteriora-

tion is the result of electrolytic action on corrosion, involving the liberation of hydrogen in the nascent state which is absorbed by the metal. On remelting and casting, the hydrogen is evolved in the molecular condition and produces pinholes.

The electric heating of annealing furnaces has in its short period of development of ten years brought considerable improvements in quality in the product, also in the non-ferrous metal industry, and the application of electric furnaces for non-ferrous metals, with special reference to bright annealing, is described by Messrs. H. C. Kloninger, G. Keller, and H. Meuche, in which they refer to the main types of furnaces used for the bright annealing process and the improvements made in the quality of the product as well as in simplifying the handling of the annealed metals.

A method has been developed whereby the macro-structure of aluminium-silicon alloys can be revealed. The reagent used is a solution of cupric chloride containing from 150 grms. to 160 grms. per litre, and the technique is described by Mr. W. Hume-Rothery. Etching, he states, is carried out by immersing the specimen several times in the copper-chloride solution, the deposit of copper being removed between each immersion. A final brightening can be obtained by treatment with a dilute solution of chromic acid. The preparation of the specimen, and the details of the etching process, are described, and have been tested for alloys containing 5, 10, and 11% of silicon respectively.

The cause of isolated cases of failure in bars of high-tension brass is shown by Messrs. J. E. Newson and A. Wragg to be due to residual stresses developed by the reeling process for straightening, after extrusion, which cause internal cracking during storage or on subsequent machining. The authors have found that suitable low-temperature annealing treatment effectively removes all possibility of residual cracking.

SECOND TECHNICAL SESSION.

The study of the alloys of silver and mercury forms part of a research carried out in the Department of Metallurgy of the National Physical Laboratory on behalf of the Dental Investigation Committee of the Department of Scientific and Industrial Research, with the object of determining the constitution of the silver-tin-mercury alloys. The results of the investigation are presented by Mr. A. J. Murphy, and the paper includes an appendix on the X-ray examination of the system silver-mercury.

The constitution of the alloys of silver and mercury has been determined over a range of temperature extending from the melting point of silver to —50° C. Progressive additions of mercury to silver cause a continual reduction in the temperature of the initial freezing point down to —38·8° C., the freezing point of mercury. No alloy in the series has a freezing point lower than that of pure mercury. Silver can retain in solid solution 55% by weight of mercury at 276° C., the amount probably increasing somewhat at lower temperatures. Two intermediate phases of restricted composition are formed. The β-phase contains 40% of silver and dissociates on heating at 276° C. into α and liquid. This phase has a close-packed hexagonal lattice in which $a = 2{\cdot}98$ Å, and axial ratio $c = 1{\cdot}62$. The γ phase contains 29–30 per cent. of silver, and dissociates on heating at 127° C. into β and liquid; it has a body-centred cubic lattice, with side 10·0 Å.

Wire Drawing.

A great deal of experimental work has been done with wires in England, Germany, and the United States, but almost invariably the wires used have been of quite small diameter. In order to minimise as far as possible the risk of error due to possible inequalities, chemical or physical, in the materials and to imperfections in the shape and surface of the dies used, Messrs. W. E. Alkins and W. Cartwright have investigated the behaviour of wires or rods of large diameter, having built up and drawn rods of $\frac{3}{4}$ in. diameter. In the results of the investigations, the authors have made no attempt to offer any theoretical speculations or deductions. In this work composite round rods, built up by drawing a number of tubular layers of equal thickness over a central solid core, have been drawn in drafts of varying amount through straight-sided dies of three different angles. It has been found that butt ends when drawn through the dies become concave without showing any steps between the layers, the concavity increasing with the angle of taper of the die and also with the amount of reduction at the draft; further, it has been shown that all the layers undergo a proportionate reduction in thickness, and therefore the same relative reduction in area of cross-section.

The boundary surfaces between layers, which are cylindrical both before and after drawing, assume in the reduction zone the form of surfaces or frusta of a series of cones of common axis and common apex; the apex of these cones is identical with that of the cone defined by the bearing of the die. The more nearly the individual layers approach the centre of the rod the farther back from the emergent side of the die is reduction found to commence and to finish. The loci of incipient reduction, of equivalent stages of reduction, and of completed reduction, are a series of spherical caps, radially parallel to one another and bounded by the bearing of the die, all of which have a common centre at the apex of the cone, the surface of a frustum of which forms the bearing of the die. Reduction thus appears to be effected by pure shear stress. The authors suggest that the behaviour of these composite rods is exactly comparable with that of solid round rods under similar conditions.

A second part on this subject by Mr. W. E. Alkins was taken as read, and is to be discussed in writing. It contains an account of a series of experiments carried out with the object of establishing the relationship between the amount of reduction of area of an annealed high-conductivity copper rod when cold-drawn (*a*) by single drafts of increasing amount, and *b*) by successive drafts of varying severity, and the tensile strength of the resulting drawn rods.

Investigations on the drawing of non-ferrous wires, by Messrs. F. C. Thompson and E. L. Francis, show that the tension is independent of the speed of drawing over the range from about 20 ft. to 600 ft. per min. In addition, proof is advanced that the pull necessary is directly proportional to the reduction of area affected. A comparison is made between the efficiency of steel, carbide, and diamond dies; the influence of the angle and contour of the die is investigated under various conditions, and the problem of lubrication is discussed and an attempt made to estimate the coefficient of friction between the wire and the die.

Application of the Spectrograph to the Analysis of Non-Ferrous Metals and Alloys.

Of recent years there has been an increasing and widening interest in the application of the spectrograph to the examination of metals and alloys, and it is slowly but surely becoming more recognised as an indispensable piece of apparatus in a metallurgical laboratory. In view of the complete and rapid survey which can be made of the composition of a metal or an alloy, it is rather remarkable that the value of the spectrograph has not been more fully appreciated by chemists and metallurgists. The day is approaching, however, when the spectrographic examination of metals and alloys must take its place alongside chemical methods, and the discussion of the subject in the paper by Messrs. H. W. Brownsdon and E. H. S. van Someren will undoubtedly facilitate the arrival of that day. In this paper the authors give some reasons for the slow development of the spectrographic methodsan examination. They consider the spectrograph as an essential part of the equipment of a metallurgical laboratory and review the possibilities and limitations of spectro-

graphic methods. Routine methods for the examination of brass and some lead alloys are outlined, and tables are given indicating the relationship between impurity or minor constituent concentration and relative line intensities.

Further work on spectrographic assay lead alloys is contained in a paper by Mr. D. M. Smith, which was discussed in conjunction with the previous paper. It gives an account of the application of the spectrograph to the quantitative determination of low percentages of tin, antimony, and cadmium in lead alloys; a routine method is described specially applicable to the binary and ternary alloys of lead used in cable sheathing, etc.

The method is based on standards of known composition either synthetically prepared or determined by accurate chemical analysis. One of its great practical advantages is that it is very much more rapid than ordinary chemical assay of these metals. Spark spectra are preferred as giving more consistent results than arc spectra.

By simple direct comparison of spectra the constituents can be determined within the range 0·1–1% with an accuracy of ± 10% (thus a percentage of 0·25 would be determined with certainty as being between 0·22 and 0·28%), and by the application of the logarithmic sector method a similar accuracy for a range up to 3% tin can be obtained.

Gold-Copper Alloys.

Two papers on this subject were discussed together, one by Messrs. J. L. Haughton and R. J. M. Payne contained results of investigations with the object of obtaining temperature-resistivity curves on gold-copper alloys which had not passed through the transformation. By recording autographically the variation of resistance with changing temperature of alloys of composition ranging between 20% and 70% atomic of gold, and by measurements of the specific resistance of alloys slowly cooled to room temperature, the transformations in alloys with compositions in the neighbourhood of those corresponding with the compounds AuCu and $AuCu_3$ have been confirmed, and the presence of another transformation in alloys approximating to the concentration of compound Au_2Cu_3 has been established. The microstructure of the alloys has been studied, and a few alloys have been subjected to X-ray examination.

The second paper on the subject contained the results of investigations of the system gold-copper by Messrs. N. S. Kurnakow and N. W. Ageew, and using the methods of physico-chemical analysis. In order to investigate the transformations in these alloys, the method of determining the electrical resistance at high temperatures and recording it by means of Kurnakow's registering pyrometers was employed. Both annealed and quenched alloys were studied. The existence of the compounds AuCu and $AuCu_3$ has been confirmed by constructing isothermal diagrams of the electrical resistance, and the limits of the solid solutions have been indicated. The nature of the formation and dissociation of both these compounds has been studied by the electrical resistance method, and the volume changes in the alloys have been determined.

Testing Copper and Copper-rich Alloys.

With the object of obtaining representative data on copper and copper-rich alloys, Messrs. Maurice Cook and Eustace C. Larke have carried out a course of routine physical testing with various machines now generally employed. Tensile, hardness, and cupping tests have been carried out on H.C. copper, 95 : 5 copper-zinc alloy, 70 : 30 and 64 : 36 brass, and 80 : 20 cupro-nickel in the form of strip 0·06, 0·04, 0·02, and 0·01 in. in thickness prepared in accordance with prevailing commercial practice. Each material at each of the four thicknesses was prepared and tested in four different tempers, varying from fully annealed to hard rolled, and the results are claimed to be typical of those obtainable in the course of routine testing with machines in general use.

Consistent results for tensile strength and elongation are obtainable on all the materials down to and including 0·02 in. thickness. One of the most—if not the most—satisfactory methods of measuring hardness, especially having in mind the requirements of routine control testing laboratories, where the ease and rapidity with which tests can be carried out is a most important feature, is the diamond pyramid static indentation method. Cupping machines, although they may measure some kind of ductility and, if properly correlated, may afford a good sound indication of the behaviour of a material for cupping and drawing operations, are limited in respect of specification work because of the variability of results given by different machines.

Brittleness in Copper.

In view of the limited time available for the discussion of papers, many, in addition to some already mentioned, were taken as read, and are to be discussed in writing. Amongst these is a paper by Mr. Clement Blazey, which is based on a continuation of earlier experiments published in the *Journal of the Institute of Metals*, 1927 and 1929, on brittleness in arsenical copper. The author has found that the brittleness is not restricted to arsenical copper, but may be produced in copper free from arsenic. The necessary conditions *so far discovered* appear to be thorough poling of the copper and the presence of a small quantity of bismuth. The investigation has not yet brought to light any element, other than bismuth, which can be regarded as a contributory cause of brittleness.

The author shows that brittleness is developed by cold-working the copper and annealing it in one of three ways—viz.: (*a*) By annealing below a certain critical temperature which is in the neighbourhood of 650° C. (*b*) By slowly cooling it from above this critical temperature to any point below. (*c*) By quenching from above the critical temperature and reheating just below it. When the copper is annealed above the critical temperature and quenched, it is quite free from brittleness.

The Attack on Mild Steel in Hot-Galvanising.

Mr. Edward J. Daniels describes an investigation dealing with the solvent action of molten zinc of varying composition on a typical mild steel, which forms part of a systematic study of the various phases of the hot-galvanising process being carried out by the British Non-Ferrous Metals Research Association. Experiments have been carried out in the laboratory to determine the rates of attack on mild steel strip when immersed in different brands of zinc (high-grade and G.O.B.) at various temperatures between 432° C. and 540° C. The influence of the addition of small percentages of aluminium, antimony, and tin has been investigated, and the action of alloys of zinc and cadmium has also been studied.

A full discussion is given of the application of the results obtained to the problem of galvanising kettles, and confirmatory data obtained by examination of an actual kettle are presented in support of the deductions arrived at from the laboratory experiments. The evidence given suggests that careful consideration of the relations between output, type of fuel, and methods of heating and heat control, leading to a redesign of galvanising equipment, should ensure a considerably longer life to kettles than the most careful and fortunate galvaniser is able to obtain to-day.

The Oxidisation of some Copper Alloys.

This paper by Mr. J. S. Dunn contains the results of an investigation of the behaviour, under oxidising conditions, of copper-zinc alloys containing from 60 to 100% copper, with respect to time, temperature, and composition of alloy, and it is shown that they fall into two classes, fairly sharply separated. Those with copper contents below about 80% all oxidise at essentially the same rate, and all

give rise to an oxide which is almost pure zinc oxide. Those with copper above about 86% oxidise at approximately the same rate as copper, and the oxide contains the metal in the same proportion as the original metal, the first or zinc oxide-forming class oxidise at about one-eighth of the rate of the second or copper oxide-forming class.

Experimental work with chlorine compounds have been found to accelerate the oxidation of brasses with a simultaneous increase in the copper content of the scale. The author associates red staining on pickling with this accelerated oxidation. The influence of the addition of small quantities of a third metal has been investigated, and the results show that small quantities of arsenic and nickel are without influence on the course of oxidation, but aluminium, even in such small proportions as 0·1% has a marked protective effect, whilst 1·9% of aluminium almost entirely inhibits oxidation at temperatures up to 800° C.

Three copper-silicon alloys with silicon content up to 4·5 were examined, and while the silicon confers some measure of protection at 725° C., at 827° this effect breaks down, and anomalously shaped oxidation velocity curves are found associated with oxide films containing practically no silica.

Copper-Magnesium Alloys.

The equilibrium diagram of the alloys of magnesium and copper has been constructed from thermal and microscopic data, and is given in a paper by Mr. W. R. D. Jones, which forms the fourth part of an investigation by the author on the constitution of copper and magnesium. Magnesium and copper form solid solutions to a limited extent. At the ordinary temperature 0·02% copper is soluble in magnesium and 2–2·2% magnesium in copper. Two compounds Mg_2Cu and $MgCu_2$ exist which do not form solid solutions but form eutectic series with each other and with the solid solutions of copper with magnesium, and of magnesium in copper. The compound MgCu is not formed in the solid state. A review of previous work is given.

Work-hardening Capacity and Elongation Properties of Copper.

There is need for criteria of the work-hardening capacity of materials used in pressing operations and other forms of cold-working processes, and Messrs. Hugh O'Neill and J. W. Cuthbertson have studied copper in this respect, and in a paper devote attention to the property of tensile elongation in comparison with results from ball-indentation tests. Various methods of obtaining the elongation values of tensile test-pieces have been applied to specimens of copper in the annealed and increasingly cold-rolled condition. Indentation tests which may be considered to estimate the work-hardening capacity have also been applied to the same specimens for purposes of comparison.

So far as they go, the results of this work indicate that (*a*) the Tetmajer "uniform elongation" value, and (*b*) the "extensibility"—*i.e.*, $(1 + a)$, where a is the index in the Bertella-Oliver elongation equation, are reliable measures of the work-hardening capacity of a metal. They present no difficulty in their determination, being calculated from observations on an ordinary tensile test-piece with two, or preferably more, gauge lengths.

It also appears that the percentage elongation on a single-gauge length chosen so that

$$L \blacktriangleleft 15\sqrt{A},$$

may be used as an index of strain-hardening capacity. These various elongation values should be reliable guides to the suitability of a metal for deep pressing operations.

Diameter Measurement of Brinell Indentations.

Mr. Hugh O'Neill also contributed a note recording an effect recently encountered during the Brinell testing of cold-rolled copper, in which it is shown that the diameter measurement of Brinell ball indentations depend to a not unimportant extent on the nature of the illumination used with the measuring microscope. Owing to shape of the lip of the indentations in certain cold-worked metals, diameter measurements of the indent may differ by 3 to 4% according to whether vertical or oblique illumination is used with the measuring microscope. The conditions are described under which variations have been noticed in testing cold-rolled copper.

Melting Nickel-Chromium Alloys in Hydrogen.

In a previous investigation published in the *Journal of the Institute of Metals*, 1928, Smithells, Williams and Avery showed that nickel-chromium alloys could be satisfactorily prepared by melting in hydrogen. The original experiments were carried out on a small laboratory scale, but with the installation of a suitable induction furnace, the effect of time of treatment in hydrogen and various methods of obtaining sound ingots have been more thoroughly investigated by Messrs. C. J. Smithells, S. V. Williams, and E. J. Grimwood. The results given in this paper show that sound ingots can be produced by this method provided that all the oxides present in the melt are reduced by hydrogen before casting. If any oxides remain in the melt, these are reduced by hydrogen, which is liberated at the moment of solidification, with the formation of steam, which causes blowholes. For casting in air, it is necessary to displace the hydrogen with nitrogen before pouring.

The effect of using various grades of raw materials in the preparation of the alloys has been studied. Alloys prepared from commercial materials have been found to give better resistance to oxidation than those prepared from pure materials. The probability that the presence of certain impurities has a beneficial effect was confirmed by making deliberate additions of elements known to be present as impurities in the raw materials.

The authors confirmed the superiority of the nickel 70, chromium 20, and molybdenum 10% alloy, referred to in the previous paper.

The process of hydrogen melting of nickel-chromium alloys is being applied on a commercial scale; it has also been used with success for the preparation of other metals and alloys in a ductile state without the use of the usual deoxidisers.

Influence of Variations in Heat-treatment and Ageing on Duralmin.

Experiments have been carried out with the object of showing the influence of the temperature of the quenching liquid and the temperature of ageing on the physical properties of duralumin, and the results form the basis of a paper by Professor A. von Zeerleder. The author states that quenching in hot water or in oil causes less deformation, and that if the temperature of the quenching medium, as well as the ageing temperature, be 50° C., they have no disadvantageous influence on the physical properties. On the contrary, measurements of the electrochemical potential, electrical conductivity, tensile and corrosion properties showed that a temperature of 145° C. (293° F.) had a decidedly disadvantageous influence. A possible explanation for this phenomenon is to be found in the effect of different annealing temperatures on the potential of aluminium-copper alloys. Finally, the cooling of sheet packets is examined during the period between being taken out of the heating furnace and being quenched.

Foundry Reopens.

Messrs. Dorman, Long and Co., Ltd., have secured an order for 5,000 tons of coke-oven doors through their subsidiary company, the Tees-side Bridge and Engineering Co., and it has been decided to reopen one of the foundries at the Port Clarence Works. The order has been placed by Messrs. Simon Carves, Ltd., in connection with an important contract they are carrying out on behalf of the Russian Government.

Shipping Exhibition at Olympia

This Exhibition promises to outstrip its predecessors not only in size and scope but in general interest. It incorporates the latest advances in mechanical and metallurgical science.

THE adverse conditions under which this exhibition has been prepared were not apparent at the ceremony on September 10, when it was officially opened by Sir Austin Chamberlain, First Lord of the Admiralty. Before a large and distinguished assembly, Sir Austin, in declaring the exhibition open, said he was present in an official capacity to express the interest and sympathy of the Government in general and the Admiralty in particular in this great exhibition. Commenting on the great stress and anxiety borne by the business world during the last few years, he said that on no section of enterprise had economic distress fallen more heavily than on those branches of trade, commerce, and industry which were represented in the exhibition.

At the subsequent luncheon, presided over by the Admiral of the Fleet Lord Wester Wemyss, the president of the exhibition, very interesting telephone communications were heard by the guests, with the assistance of loud speakers. Calls were received from two Atlantic liners through their Marconi telephone equipment—Captain Latta, speaking from the *Empress of Britain*, some 700 miles west of the Scilly Isles, and Captain Bulman, of the *Homeric*, whose ship was 150 miles west of Cherbourg. The two commanders wished the exhibition success, and talked with Lord Wemyss for some minutes, the guests hearing the conversations as plainly as the president.

In proposing the health of Sir Austin Chamberlain, Sir Alan G. Anderson, chairman of the Orient Line, spoke of the fine example of courage that had been given by the political leaders of the country during the past week. They had come forward to prescribe a dose of extremely unpleasant medicine for a recalcitrant patient, and everyone present was very proud of them. In acknowledging the toast, Sir Austin said it had been a most gratifying encouragement to him to see the effort which British industry was making and the success which was attending that effort, even in these troublesome days, as illustrated in this exhibition.

In a previous issue some advance information was published regarding some of the exhibits, and, as promised, further information is contained in the following review. This exhibition of shipping, engineering, and machinery is a very comprehensive one, and it has only been possible to refer somewhat briefly to some of its outstanding features.

Metallurgical Features.

The gradual increase in pressures and working temperatures of boilers and the greater refinement of machinery to cope with increased speed now being demanded from many types of vessels have necessitated the introduction of materials capable of withstanding high duty conditions. During recent years many researches have been in progress on metals and alloys with the object of meeting these special conditions, and the results are in many instances exhibited at Olympia.

The numerous applications of stainless steel are well illustrated by the displays of Messrs. Brown Bayley and Messrs. Thos. Firth and John Brown, Ltd., particularly with regard to its use for turbine blading and special fittings. The display of Staybrite by the latter firm is particularly pleasing. This high quality rustless steel has a special value for stateroom, deck, and kitchen fittings. Special heat-resisting steels as well as a wide variety of other alloy steels are not the least interesting of these exhibits.

Centrifugal castings manufactured by the Sheepbridge Stokes Company's process are exhibited. These are in grey cast iron, and also an alloyed cast iron suitable for hardening by heat-treatment. A feature of this exhibit is nitralloy cast iron and steel, suitable for casehardening by the anhydrous ammonia process. This firm include among their specialities centrifugally cast piston rings, as do the British Piston Ring Co., which is also exhibiting.

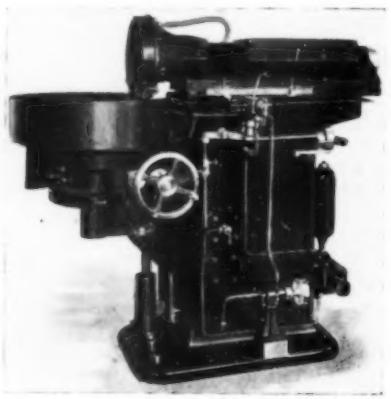

Fig. 1.—Surface-grinding machine.

In regard to non-ferrous metals used in marine engineering and shipbuilding, the bulk percentage in comparison with iron and steel is small, but it is of almost vital importance. Special alloys, resistant to corrosion, have an important influence in overcoming marine problems. For this purpose the Mond Nickel Co., Ltd., are displaying a range of products for which they are noted, while the Birmingham Battery and Metal Co., Ltd., are showing special cupro-nickel and aluminium-brass condenser tubes. The results of research work under the direction of the British Non-Ferrous Metals Research Association are displayed by I.C.I. Metals, Ltd., in their Alumbro condenser tubes. These are of aluminium bronze, and are a comparatively recent production, but the results obtained from them are most gratifying. Associated with this exhibit are the super-nickel tubes, manufactured by this company, which contain 30% nickel and are recognised for their corrosion-resistant qualities. The Yorkshire Copper Works also exhibit cupro-nickel tubes as well as Yorcalbro, an aluminium-bronze alloy designed to resist corrosion, tubes from which are produced at low cost. In addition, these firms display a wide range of tubes in various metals and alloys.

Antifriction metals of every description are shown by Fry's Metal Foundries, Ltd., and this firm's recent advances in the production of die-castings are well illustrated by a complete range of work in all standard alloys, including those having a tin, lead, zinc and aluminium base. But it is in the display of brass and yellow metal die-castings that recent progress is more adequately displayed. These undoubtedly accentuate the potentialities of this important process. Antifriction bronzes are displayed by "Poro" Metal, Ltd., which are made under a special process and claimed to have greater life than ordinary bronzes.

Welding and Cutting Equipment.

The rapid progress of welding is influencing the development of welding machines and equipment and the Exhibition includes a very comprehensive display of the latest developments. The Murex Welding Processes, Ltd., display plant and electrodes to meet all requirements of the engineering trade, including the latest design of motor generator set, together with the electrodes Belfinish, Special A, Medex, as well as other electrodes for welding special alloys, both ferrous and non-ferrous.

Demonstrations assist in dealing with problems that are discussed, which also assist in removing prejudices still operating against the use of welding. The Quasi-Arc Co., Ltd., British Insulated Cables, Ltd., and the British Oxygen Co., Ltd., also have effective displays of various types of electric welding machines, and in addition the latter company incorporates oxy-acetylene welding and cutting plants operating on both high and low-pressure systems. This firm display their universal oxygen cutting machine, which is capable of cutting any desired shape from steel plate, from $\frac{1}{4}$ in. to 15 in. thick. The British Oxygen Company's service at the disposal of users is well illustrated by an ingenious map, and the diversity of uses for the gases they supply is indicated to all who visit their stand.

Messrs. Siemens-Schuckert (Great Britain), Ltd., are exhibiting a large range of electric welding machines, etc. A number of new machines are shown, and special attention is drawn to the automatic carbon arc and metallic arc welding machines which are in operation. These machines are employed for welding the longitudinal and circumferential seams of vessels, for welding square containers and

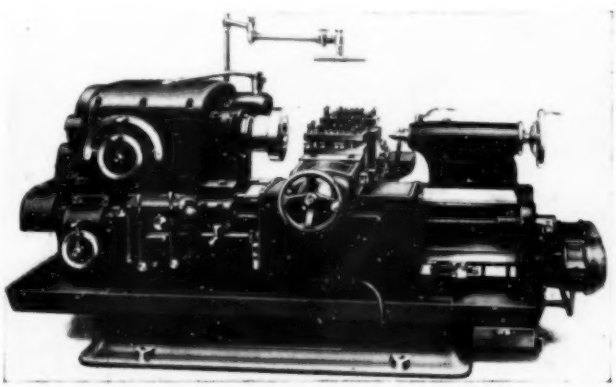

Fig. 2.—Multi-tool lathe.

other articles, such as steel pressings, etc., where a number of pieces of mild steel have to be joined. A skilled welder is not required to operate the machine. The operator presses a push button to start the machine, and the arc is automatically struck. A welding head travels automatically along the seam, or the work travels and the welding head is stationary until the seam is finished. At the end of the seam the operator depresses the stop button and the machine is ready for welding the next seam, after the head has been returned to the starting position.

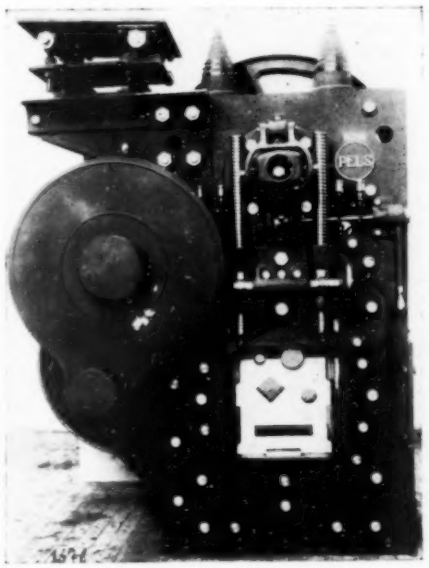

Fig. 3.—Bar cropper for rounds, squares, etc.

Fig. 4.—Cropper for dealing with joists and channel sections.

Electric Equipment.

The application of electricity to subsidiary equipment in vessels is now fully appreciated, and it is natural that the British Thomson-Houston Co., Ltd., which has had a long and close association with every aspect of marine electrical progress should be well represented. This firm is a pioneer in the design and production of turbo-electric and Diesel electric propulsion equipments, high-speed scavenging blowers for Diesel engines, auxiliary turbo-generators, main and auxiliary switchgear, which cannot well be exhibited, but a full range of D.C. or A.C. motors and control equipment is displayed, the unique features of which are demonstrated.

Another firm which has been responsible for much of the development of marine electrical equipment is the Demag Aktiengesellschaft, Duisburg. This firm, which is one of the largest in Germany, is confining its display to electric lifting appliances. The exhibits include electric blocks and double-acting hoists, the former consist of a steel jacket, which holds the rope drum in roller or ball bearings, and carries both the gearcase as well as the lifting motor, with fitted-in brake and limit switch. This block is designed for lifting from $\frac{1}{4}$ to 9 tons, and is arranged for both direct and three-phase current. The double-acting hoists are lifting appliances for smaller loads, and are only arranged for three-phase current.

Of the display of portable electric tools, an interesting range is exhibited by Black and Decker, Ltd., which includes a series of electric drills, electric sanders for sanding castings and for cleaning welding seams, etc., electric grinders and buffers, valve refacers, etc. This firm are distributors of the Van Dorn electric tools, which are among the exhibits.

The importance of maintaining readings with regularity and accuracy are appreciated by all users of electric pyrometers, and for the conditions operating on board ship the equipment must be designed to give the maximum robustness and convenience without in any way endangering its accuracy. An excellent exhibit of this kind is that shown by the Foster Instrument Co. In this equipment the

delicate moving system which carries the pointer of the indicator or the pen arm of the recorder is mounted by the "Resilia" system, by which it is protected against shocks in all directions. The wide range of electrical temperature measurement instruments includes optical, radiation, thermo-electric and electrical resistance thermometers, together with modern instruments by which automatic control is effected.

Machine Tools.

In the August issue attention was directed to a number of interesting machine tools displayed at this exhibition. This review was necessarily incomplete, and in addition to those previously described, the Selson Engineering Co., Ltd., are exhibiting a surface-grinding machine and a Weipert multi-tool lathe which have many valuable features.

The Surface-Grinding Machine by Slip Material (Fig. 1) is a hydraulically operated machine, remarkably accurate in construction, and designed for the close-limit surface-grinding of many parts at a time, the work being held by a magnetic chuck which also is made by the machine-maker. The hydraulic movement is of the relief-valve type, so balanced as to keep the machine parts moving with the desired uniform speed. Movement without tremor is sought for and obtained. The front end of the spindle is lapped into a long phosphor-bronze bearing, the rear end running in an "SKF" ball bearing. The grinding-wheel head is operated by a hydraulic cylinder which automatically moves the grinding wheel over the work-table. Grinding against shoulders is possible by virtue of the precision of hydraulic "reverse," which always occurs at the same desired point.

The work head is mounted on saddle with vertical sliding motion, and this can be adjusted either side up to 5° for conical grinding. The vertical spindle of the work-table is lapped into self-adjustable and self-centring bearings, consisting of steel against phosphor-bronze. The magnetic chuck is of the 16-pole type and is 16 in. diameter. It is waterproof. The switch is designed as a demagnetising apparatus, so that, when thrown in the "off" direction, the current is reversed, with a considerable demagnetising effect. Ample provision is made for coolant supply.

The Weipert Multi-Tool Lathe (Fig. 2) was developed to meet the demand for the simultaneous employment of several tools. The lathe is equipped with two separate carriages. The two carriages, one for roughing and one for finishing, are arranged in such a manner as to be

Fig. 5.—"Hypermill" horizontal automatic miller.

independent of each other as regards the rate of feed, or they can work simultaneously. It is interesting to note that each automatic starting of the automatic movement of the two carriages is equally independent of the other, and that the cutting speeds and the feeds are quickly and easily regulated to suit the work in progress, even during the course of this work.

The quick return of the tools to the initial position in the case of the machines with 18 in. and 30 in. distance between centres, is effected by automatic contact control of two electric motors. The headstock is of all-geared type with

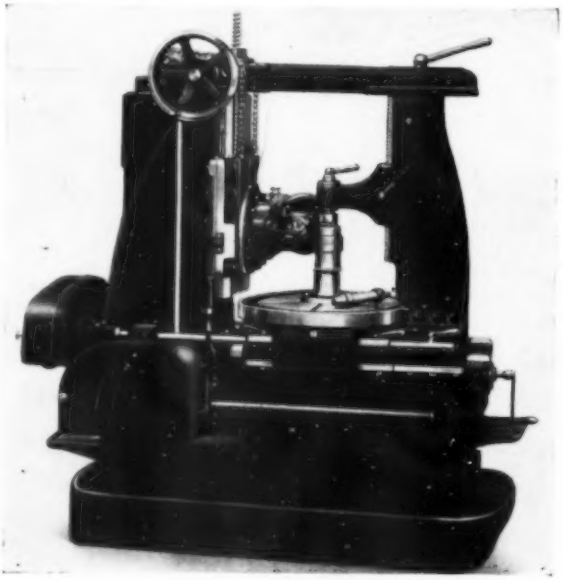

Fig. 6.—A Pfauter gear hobber.

single pulley drive. There are nine spindle speeds, quickly obtainable by means of sliding gears. A friction clutch is arranged in the driving pulley, and a brake is mounted on the head to allow of rapid starting and stopping. Provision is made to change the cutting speeds after the machine has been set up. The movement of the front carriage is derived from the mainshaft or spindle by means of spur-gearing, a four-feed gearbox being provided. By changing two wheels eight other speeds can be obtained. The change of feed is very simple—it is effected by one lever. From the feed-gear the feed-movement is transmitted by a safety coupling. The rear carriage for cross-cutting and profiling is adjusted by means of a handle in the longitudinal direction of the bed and then locked. It has on its under-side an adjustable slide, as has the front carriage. The upper side at the back has an automatic feed in a transverse direction to the slides of the bed, and has T-shaped slots to receive the tool-holders.

Of more than ordinary note are the shearing and punching machines exhibited by Henry Pel and Co., Ltd. The bar cropper, type FV, Fig. 3, for rounds, squares, flats, angles, tees, joints, channels, and other sections, is capable of high output. Made in six sizes, this type embraces many important features. The machines have double gearing; the slide carrying the upper blade is well balanced, and moves in amply dimensioned box guides provided with wearing strips. A claw clutch operated by hand and which disengages automatically at the top of each stroke is provided, and an easily adjustable downholder ensures square cuts, and also lengthens the life of the blades. Easy interchangeability of the blades in these machines is made possible by loosening a few nuts. Another cropper for dealing with joist and channel sections, and also bar, angle, and tee sections is shown in Fig. 4. This machine is made in three sizes, the smallest having a capacity for round bars up to $2\frac{1}{2}$ in. and joists up to $10 \times 4\frac{1}{2}$ in. It is designed to operate at 32 strokes per minute, and possesses all the advantageous features that efficient service demands. These machines are built on substantial lines for lasting service, and are guaranteed for a year.

The display of Messrs. E. J. Jones (Machine Tools), Ltd., which occupies two stands, covers many varied types of

(*Continued on page* 167.)

Recent Developments in Tools and Equipment

Automatic Reversal of Open-hearth Furnaces.

IT is well known that preheating gas or air, or both, before combining to form a gas mixture for producing a high flame temperature increases its heating efficiency. The gain due to preheating is, of course, specially important if it can be undertaken without any contribution of heat beyond that developed at the production and combustion of gas itself, and in practice this is generally realised. The problem of making use of the heat carried in the products of combustion was solved by Siemens, in 1857, by means of a regenerator, which, in principle, is applied to modern open-hearth steel furnaces.

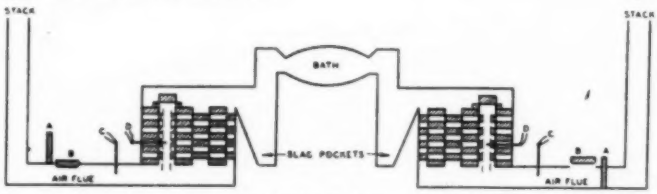

Fig. 1.—Diagrammatic drawing showing the location of the thermocouples on both sides of the furnace. "A" indicates stack dampers and "B" indicates air lids; "C" indicates the recommended location of the control (and recorder) couples in the air flues; "D" indicates the alternate location of the thermocouples in a well in the checker chambers.

The method employed in heating the air and gas in the ordinary Siemens furnace is by passing each through separate chambers, built of refractory bricks, so arranged that the surface area exposed is considerable. For this purpose the brickwork in the chambers is checkered. Two pairs of chambers or checkers are used, so that air and gas are introduced from one pair at a time, the waste gases passing through the opposite chambers, giving off considerable heat, which is absorbed by the checker brickwork. After an interval, which varies, the process is reversed by operating valves, which shut off air and gas from one side and introduce them from the other. In this way the air and gas are preheated before they enter the furnace chamber.

There are two modifications of the ordinary Siemens furnace: one in which the gas producer and furnace are combined, and which have air regenerating chambers only, the gas being supplied direct from the producer; the other, in which both gas and air pass through regenerating

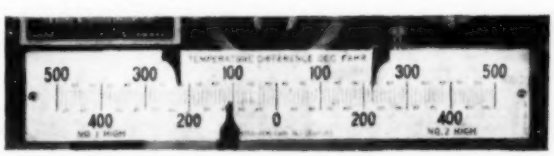

Fig. 2.—Scale of the Reversal Controller with the temperature-difference limits of the indices set at 220° F. Moving index at bottom of scale shows present temperature-difference.

chambers. Although there are many kinds of open-hearth furnaces, they differ in constructive details only, the principles of the process remaining the same.

The change-over valves to effect reversal are a very important part of the whole regenerator construction, but, in addition to these, it is necessary to have regulators for varying the quantities of air and gas as well as the chimney draft. In open-hearth furnaces it is customary to place regulating dampers in all the four conduits between the change-over valves and the chambers. To obtain the highest efficiency from the regenerators, however, the time of reversal should be accurately determined and consistently maintained. For long the reversal of a regenerative furnace has been based on an empirical time-cycle, but recently a more efficient system has been developed which operates automatically on a temperature-difference principle. It is the result of a thorough investigation by engineers of Leeds and Northrup Company, the principal object of which was to establish a reversal control based upon the actual conditions occurring during operation of the furnace, in order (1) to return to the furnace a greater amount of heat; (2) to establish and maintain a balanced thermal condition between the two sides of the furnace; (3) to provide absolute freedom for the operator in developing or building-up the heat head during the progress of each heat; and (4) to provide a safeguard against early burning-out of the regenerative chambers.

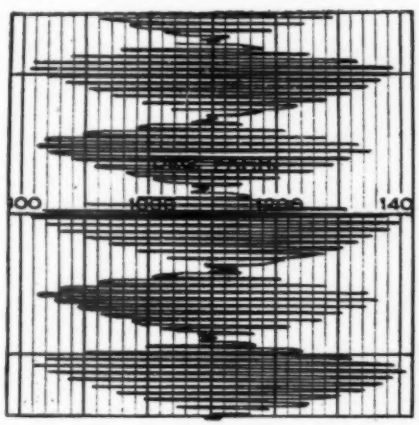

Fig. 3.—Section of the typical record made by the Two-Point Recorder, showing the balanced temperature conditions in the regenerative system.

Many different methods of reversal—both from temperature and from time, some automatic, some semi-automatic, and some entirely manual—were tested in actual commercial operation. Heat absorption, heat loss, thermocouple location, valve operation, fuels—in brief, the factors affecting operation—were carefully investigated and tabulated under varying conditions. In actual commercial operation on a number of different furnaces, the automatic temperature-difference method has proved to be the superior method for open-hearth furnace reversal.

The weakness of the manual reversal is the uncertainty of the operator's response to the demands of the furnace. Even when the operator has pyrometric guidance, he will rarely reverse the furnace at the proper instant; whereas, with this new automatic reversal method, the furnace itself may be said to decide when it should be reversed. Heat conditions within an open-hearth furnace change rapidly. As the checker system on the side which is heating up approaches a certain temperature—its so-called "point of saturation"—the rate of heat absorption decreases rapidly. This means, of course, that as this point is neared, increasing quantities of heat go out of the stack. Thus, there is one correct point for reversal, a point which is variable not only with every furnace, but also with each reversal during any one heat, throughout the campaign of a furnace. To delay reversals beyond this point would cause a waste of heat which could and should have been turned back into the furnace. The correct point for each reversal can be established in practical operation by means of an automatic temperature-difference reversal controller. Regardless of furnace design, age or efficiency, this controller will act at the point at which the furnace should be reversed for greatest effectiveness.

This automatic reversal equipment consists of a controller and a two-point recorder for showing air-flue or

checker-chamber temperatures. Two thermo-couples for the controller are installed in the flues or checker chambers as suggested in the diagrammatic illustration, Fig. 1. Couples for the potentiometer recorder are located directly adjacent to the control couples, usually in the same protecting tubes.

The controller may be located wherever it is most convenient. Usually it is mounted on a panel with the recorder and located on the charging floor, opposite the furnace. When the temperature of one couple exceeds the temperature of the other by a predetermined number of degrees, the controller reverses the furnace. The scale on the controller, shown in Fig. 2, is calibrated to show the total difference setting on each side of the zero point, and it is a simple operation to adjust the contact points along the scale to the temperature difference at which the control is set. Thus, reversal may be made as frequently as desired, without disturbing the heat balance, simply by narrowing the temperature-difference limits set on the controller.

The Leeds and Northrup automatic temperature-difference reversal method has been installed in many open-hearth furnace plants in the United States, and the results indicate that the method effects economy and gives improved efficiency. In open-hearth furnaces fitted with this control fuel costs have been reduced more than was thought possible: furnace production has increased, refractory costs have been reduced, and the over-all efficiency of the furnaces has been raised because of the more regular operation. Correct heat balance is maintained continuously on both sides of the furnace, as is shown by an actual size record made by the two-point recorder, illustrated in Fig. 3, from which it can be assumed that, since the maximum temperature of preheat is maintained and the cycle of preheat is controlled, the combustion rate and flame temperature within the furnace are controlled. Further information regarding this automatic reversal method is obtainable from the Integra Co., Ltd., 183, Broad Street, Birmingham, the sole British agents of the Leeds and Northrup Company.

A NEW HEAT-TREATMENT FURNACE.

THE selection of the most suitable heat-treatment furnace is frequently a difficult problem when such a form of equipment is required to be installed. So many factors are usually raised with the object of assisting in the determination of the type of equipment, particularly in regard to the form of heat energy to be used, that the main factors may easily be overlooked. After all these factors have been discussed, however, it will ultimately be appreciated that the measure of the utility of a furnace is dependent on the quality and overall cost of the finished product. Thus, the real problem, from a manufacturer's point of view, is that of manufacturing a product of high quality at low cost, and of using that type of furnace and that medium of heat energy which will give this result under his particular manufacturing conditions.

The question as to whether fuel or electricity is most suitable is an important one, but it should be appreciated that solid, gaseous, liquid or pulverised fuels, as well as electricity, have each a distinct field of usefulness, and each has limitations; it is therefore necessary to determine which has the most practical value in meeting the conditions under consideration.

The electric heat-treatment furnace under review is designed by Messrs. August Muffle Furnaces, Ltd. As the detailed description will show, the aim has been to produce a robustly constructed unit for the specific range of work for which electrical heating is best. The design appears admirably to suit the policy of the firm's production scheme, which in turn covers a range of types and firing methods broad enough to provide the most suitable for the work in hand and the conditions of operation.

It is well known that the characteristics of the electric furnace are distinct. The heat value of the k.w.h., for instance, is a constant value and not an average value, and the energy is converted without combustion; thus, conditions inside the furnace are such as to be independent of individual control; further, the use of electricity facilitates accurate control of energy. The cost of electric energy measured in B.th.u. is usually higher than that for fuel, but the indirect advantages associated with its use frequently make possible a lower production cost. Thus, in electric heating equipment, the products of combustion are eliminated, there is an absence of heat and odour

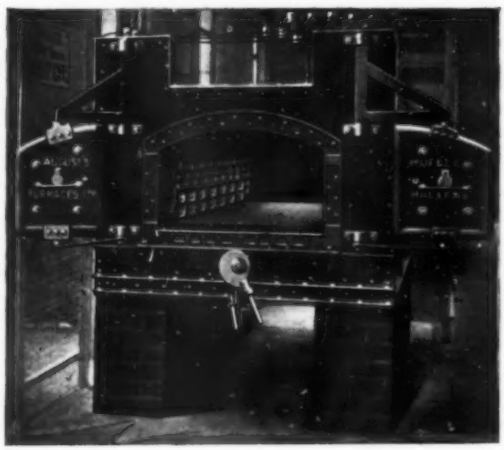

Fig. 1.—Inside of furnace showing elements.

from spent gases, the atmosphere inside the furnace is under control, the temperature control is automatic, and generally its use tends to establish new standards of production.

In the August furnace the current supply is 200 volts, 50 cycles, 3-phase, connected through a Brookhurst triple-pole straight-on contactor, complete with T.P. isolating switch and overload trips, and a 35-k.v.a. transformer. Cambridge automatic temperature control equipment is also fitted.

The furnace is of the box-resistance type, constructed for batch heating, as shown in Fig. 1. Inside the mild-steel shell is adequately lined with high-grade refractory insulating material, to reduce heat losses to a minimum, and to ensure high thermal efficiency. The charging door is in halves, and is of a special type. It is suspended in such a manner that the hot face can always be turned away from the operator. It sockets well into the door-opening, and can be opened to any desired extent. Special insulating refractory is used for the door blocks, asbestos mill-boarding forming a backing to reduce heat losses. A door "dead" switch is fitted which automatically cuts off the current when the door is opened.

The heating chamber is rectangular in shape, 60 in. by 30 in., with an arched roof, a nickel-chromium heat- and scale-resisting plate forming the hearth. The heating elements are of the open type, and are composed of "hair-pins" of quality nickel-chromium-alloy tape, of robust section. An interesting feature is the method of maintaining these elements in position. They are threaded through rings of similar material, each ring being securely anchored to the brickwork of the chamber and located sufficiently close to adjacent rings to preclude the possibility of the elements coming into contact with one another. The elements are distributed over the full length of the chamber, on the roof, side walls, and hearth, giving an even temperature throughout the chamber. Special nickel-chromium guards protect the side elements from mechanical damage with the minimum of radiation interference. The wide distribution of the elements tends to place less dependence upon indirect radiation, and increases the amount of space that can be profitably occupied by the charge.

An ingenious arrangement of the elements at the back of the furnace renders them easy of access when the furnace is in operation. The "hairpins" are thickened at the ends and led out through the back wall to a neat terminal board, which is enclosed in the false back, as shown in Fig. 2.

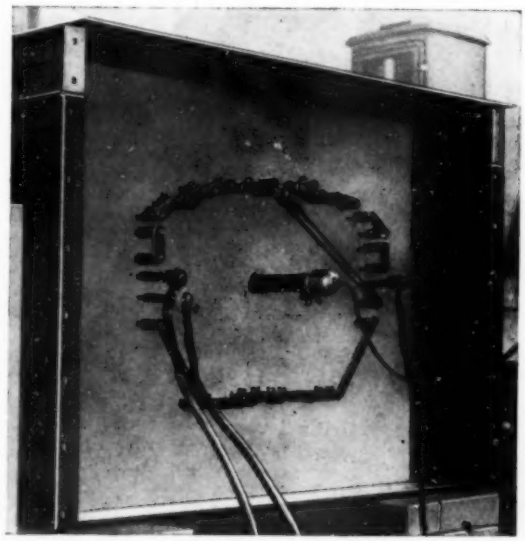

Fig. 2.—Terminal board enclosed in false back.

The system of wiring the phases in three banks of electrodes, together with the method of element suspension and connection, facilitates the removal of a faulty hairpin whilst the furnace is hot, and operations can be safely and efficiently continued by merely shorting the hairpins adjacent to it on the terminal board, Fig. 2. At the same time, a new hairpin can be substituted while the furnace is still hot and without serious loss of time.

The furnace is designed for heat-treatment operations involving temperatures up to 1,000° C., but by introducing a "change-over switch" and a slightly modified transformer, to enable the secondary winding to be "delta" connected, the same furnace becomes eminently suited for the treatment of aluminium alloys and similar low-temperature work for which the temperature is not required to exceed 500° C. In its present form the cold furnace can be raised to a temperature of 900° C. in from 2½ to 3 hours, and whilst soaking its charge at this temperature the insulation of the furnace is such that no power whatever

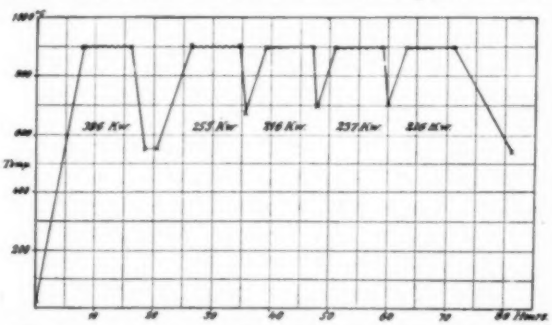

Fig. 3.—Current consumption in casehardening batch work.

is being used for approximately 80% of the soaking time. Particulars of current consumption in casehardening with this furnace are shown in Fig. 3. Five charges, each of an average weight of over 7 cwt., were made, each charge being given a soaking time of 8 hours. It will be noted that the furnace maintains a relatively high temperature during the time a batch is removed and a cold batch charged.

Shipping Exhibition at Olympia.

(*Continued from page* 164.)

machine tools, the majority of which are under power and operating on suitable work, and workshop equipment. A feature of this exhibit is the grouping of a number of standard toolroom machines, while a large lathe weighing 12 tons and small drilling machines of about 10 lb. are shown. The Werner milling and grinding machines attract much attention. Of these the new Werner Duplex Automatic Splineshaft Grinding Machine is of particular interest to automobile and similar manufacturers. The machine incorporates a hydraulic drive system for the operation of the table traverse, the indexing heads and the tailstocks, and electro-magnetic devices for feed and locking motions, and undoubtedly represents very advanced practice. Two shafts are mounted together on the machine, and one is ground on the spline cores while the other is ground on the flanks, thus avoiding the necessity of two single spindle machines for the separate operations, or successive operations with different set-ups on one machine.

Werner Milling Machines include a high-power plain milling machine, with automatically controlled rapid intermittent table traverse, a horizontal manufacturing milling machine, with quick power traverse of table, also automatically controlled, and a Universal milling machine. The first-named machine is constructed on the braced-frame principle, the knee being supported at its outer end by an upright which is bolted to the base, and which can be tied to the overarm by a further support, the latter being a light metal casting to facilitate handling. Control is by single hand-wheels with direct reading indicators for speeds and feeds, and a single hand-lever, in addition to automatic control for the table motions. Automatic lubrication is applied throughout. On the Manufacturing Milling Machine the quick-power table traverse is driven by a separate self-contained motor. The control of the table movements—*i.e.*, quick traverse in both directions and normal machining feed, and disengagement of spindle on return of table—is controlled automatically by dogs on the table.

Another machine in this display of considerable interest is the Kaerger 5½ in. Centre Lathe, which is designed for toolroom and precision manufacturing work. A noteworthy feature of this machine is the arrangement of the drive. A motor is accommodated in the base of the cabinet leg and drives by tex-ropes to a gearbox mounted in the top of the cabinet leg, and from there by belt to a clutch pulley on the spindle. The object of such an arrangement is to make the machine more stable by avoiding excessive weight in the headstock.

An extensive display of machine tools is exhibited by Messrs. Dowding and Dickinson, many of which have not been previously shown in this country. Amongst these are included several Cuttat machines, which were first introduced at this year's Paris Fair, several models of Pfauter machines, and some Magdeburg centre and turret lathes, which were first exhibited at the 1930 Leipzig Fair. Among the exhibits is the Cuttat Oleomatic as here illustrated. The machine works entirely automatically with the exception of loading and unloading the chuck, and it swings 8 in. diameter over the slides. Hydraulic operation is furnished to front and rear tool-slides, to the chuck, and to a disc clutch for starting and stopping. While the machine is suitable for heavy roughing work, solid positive stops ensure precision on finishing. Another is the "Hypermill" Horizontal Automatic Miller, shown in Fig. 5. This machine is designed for mechanical or hydraulic table drive, and embraces a number of outstanding features.

A range of Pfauter gear hobbers is on view. One of the most modern of these is the vertical hobber shown in Fig. 6. It can be supplied with an overarm work arbor support, which, together with the upright and the bed, forms a closed rectangle, withstands all strains without deformation. These machines are standardised in a range of sizes from 4 in. to 50 in., to cover every size and pitch of gear.

Some Contracts.

Several substantial contracts have been booked for the Soviet Government. Craven Bros., Ltd., of Stockport, have secured an order for machine tools to the value of about £250,000. Priestman Bros., of Hull, have received an order for 18 excavators; and Messrs. Thos. Firth and John Brown, Ltd., of Sheffield, have secured contracts for the supply of stainless steel to the value of about £20,000. Several machine-tool makers in the Halifax area have also received substantial contracts for radial drills, turret lathes, drilling and planing machines.

Messrs. The D.P. Battery Co., Bakewell, has secured a contract for "Kathanode" batteries, for two battery-operated locomotives to be used for shunting work in connection with the extensions for the Underground Railway.

The United Water Softeners, Ltd., have secured a contract from the Doncaster Borough Council for the supply and erection of water-softening plant at the Corporation's Armthorpe Works.

The Butterley Co. has secured a contract for 600 tons of steelwork to be used in the erection of a new goods depot at Bricklayer's Arms Station for the Southern Railway.

Electroflo Meters Co., Ltd., of London, has secured an order for the complete instrument equipment for the Battersea generating station of the London Power Co., Ltd. The instruments ordered are for the measurement of the boiler and turbine steam, turbo-condensate and circulating water, temperature, pressure, CO_2, steam flow-air flow ratio, draught, etc. The contract also includes a semi-portable Venturi type feed-water test metering installation.

Wm. Denny and Bos., Ltd., of Dumbarton, have received an order from the London, Midland and Scottish Railway Co. for a steamer similar to a previous vessel built by this company. The new vessel is to be used for the Holyhead-Dublin cargo service.

Messrs. J. and C. Harrison, Ltd., of London, have placed orders for four vessels, two of which are to be built by Messrs. Lithgows, Ltd., of Port Glasgow, one by Messrs. R. and W. Hawthorn Leslie and Co., Ltd., of Newcastle-on-Tyne, and the other by Messrs. Wm. Gray and Co., Ltd., of West Hartlepool. Triple-expansion engines will be the propelling agent, and super-heated steam will be used. The machinery for the vessels built on the Clyde will be supplied by Messrs. David Rowan and Co., Ltd., of Glasgow, while the North-Eastern Marine Engineering Co., Ltd., will be responsible for the machinery for the vessel to be built on the Tyne, and the Central Marine Engineering Works at Hartlepool will build the machinery for the other vessel.

Messrs. Richard Dunston, Ltd., of Thorne, Yorks., have received an order from Grimsby owners for a steam cargo vessel, 104 ft. long, which is intended for regular service between Grimsby and Hull.

Messrs. Scott and Sons, of Bowling, have booked an order for two coasting vessels for Messrs. J. Fisher and Sons, Ltd., of Newry. The two vessels will have triple-expansion engines, built by Messrs Aitchison, Blair and Co., Ltd., of Clydebank.

Messrs. Harland and Wolff, Ltd., have received a contract for 150 ft. pontoon barge for a Carlisle firm, to be equipped with triple-expansion engines driving twin screws. The barge is to be built at the Govan works.

Messrs. H. M. Murray and Co., of Glasgow, have secured a contract from the London and North-Eastern Railway Co. for the widening of part of the line between Arbroath and Montrose.

Messrs. Harland and Wolff, Ltd., have received an order for a passenger ferry from the Wallasey Corporation, and also a twin-screw self-propelled floating pontoon for the South African Railways and Harbours.

The General Electric Co. has received a contract from the Worksop Urban District Council for supervisory control gear.

Messrs. Ferguson Bros., of Glasgow, have received two contracts, one for a dredger for London owners, and the other for a river boat for Canadian owners.

Messrs Melville, Dundas and Whitson, of Glasgow, have secured a contract for reconstructing the entrance to a graving dock at Greenock at an approximate cost of £27,000.

Messrs. The Lancashire Dynamo and Motor Co., Ltd., of Manchester, have received a repeat order for a large number of electric motors in connection with the change-over to a standard voltage at Athens, Greece. This order has been secured through the Whitehall Securities Corporation, London.

Messrs. Goodall, Clayton and Co., Leeds, are erecting coal-washing and cleaning plant at the Ashington Coal Co.'s colliery. The plant will be capable of dealing with 350 tons of coal per hour, and is estimated to cost about £100,000.

Messrs. Kitson and Co., of Leeds, have received an order for eight locomotive boilers for the Iraq Railway.

The Admiralty has placed contracts for air bottles with the Chesterfield Tube Co., Ltd.; for drills and drill sockets with the Stalker Drill Works of Sheffield, and Easterbrook Allcard and Co., of Sheffield; and for 15-cwt. air hammers from Messrs. Davey Bros., Ltd., of Sheffield.

The Crown Agents for the Colonies have placed a contract for laminated springs with Steel, Peach and Tozer, Sheffield.

Contracts for the supply of 9,500 tons of steel rails have been placed by the South African Railway Board with the Cargo Fleet Iron Co., Ltd., of Middlesbrough; the United Steel Co., Ltd., of Sheffield; and the Lancashire Steel Corporation Ltd., of Warrington.

Messrs. Dorman, Long and Co., Ltd., have secured a contract for 5,000 tons of coke-oven doors, through their subsidiary company, the Tees-side Bridge and Engineering Co. The order has been placed by Messrs. Simon Carves, Ltd., of Manchester.

CATALOGUES AND OTHER PUBLICATIONS.

It is only within fairly recent years that commercially sound methods have been evolved for the production of aluminium bronze, but progress has been such that new applications are continually being found for this very useful alloy. Messrs. Max Horton & Co., of Birmingham, who have specialised for some time in research on this alloy, have sent us a copy of their booklet "Aluminium Bronze." It contains illustrations and descriptions of their "Moxyda" and "Noxyda" products, together with a list of the many applications for which their castings sheets, strip, wire, etc., are used. Those interested should apply to the above company, 3, Newhall Street, Birmingham.

Messrs. Samuel Osborn & Co., Ltd., have sent us their latest leaflet dealing with S.O.B.V. "Solidend" Tools. The main feature of these tools is that they consist of a piece of cutting alloy of full section butt-welded on to a high-tensile steel shank. The weld is unbreakable, with the result that the full section has almost the same qualities as a solid tool. To meet the requirements of those who prefer to forge their own tools, Messrs. Osborn supply ready-welded tool blanks, not forged or shaped. A diagram of the standard shapes of S.O.B.V. "Solidend" tools is included in the pamphlet.

A catalogue recently issued by Messrs. J. Stone & Co., Ltd. Deptford, London, S.E. 14, describes all the bronze and white metal products of this firm, and shows the extent to which these metals are used in engineering, especially for transport purposes. It includes bronzes for bearings, locomotive slide valves, axle boxes, stays and brackets, levers, etc., high-tensile bronzes, acid-resisting bronzes, gear bronzes, white metals for railway use, white metals for Diesel engines, alloys for bells, and white metals for aircraft and motor-car engine bearings. Illustrations show work in progress in the company's foundries, finished products, and different types of transport vehicles incorporating Stone products. Further information may be obtained on application to the company's offices at Oceanic House, 1a, Cockspur Street, London, S.W. 1.

Faraday's Centenary Celebrations.

At the Royal Albert Hall, London, a unique scientific and electrical exhibition will be held from September 23 to October 3 to celebrate the centenary of Faraday's discovery of electro-magnetic induction. The principal object of the celebration will be to demonstrate the results of Faraday's work. Suspended from the dome of the hall will be specially woven canopy of 80,000 sq. ft. This will be illuminated by 250 concealed projectors, and the resulting reflected light, equivalent to the illumination from half-a-million candles, or 300 electrical horsepower, will bathe the arena in shadowless light. In the centre, on an impressive memorial dais, will be a statue of Michael Faraday, around which will be assembled many priceless works of scientific discovery.

Surrounding the statue are suitable sections tracing the development of Faraday's many discoveries to the present time, so that the public will see exhibited the apparatus which are the products of our scientific and electrical civilisation to-day. These sections will include electric generators, transmission and distribution, transformation, transportation, power, industrial heating, domestic applications of electricity, electrochemistry, and communication. Through the co-operation of the universities and technical schools, instructors will be available to explain and demonstrate to the general public the operation and technicalities of the exhibits

Robert Blair Fellowships.

The Robert Blair Fellowships are the most valuable scholarship awards in the gift of the London County Council. They carry a grant of £450. During the session 1931-32 they have been awarded to Mr. John H. Chesters, of Sheffield, and Mr. Donald G. Reid, of Woodford Green, Essex.

Mr. Chesters is at present engaged with the Metropolitan-Vickers Electrical Co., Ltd., of Manchester, in research work on refractory materials for use in the induction furnace. It will be remembered that, in collaboration with Mr. W. J. Rees, Mr. Chesters submitted a paper at the annual general meeting of the Iron and Steel Institute, held this year, on "Refractory Materials for the Induction Furnace." We understand that, during the time covered by the award, he proposes to study the influence of the bond on the properties of magnesite bricks.

Further Fall in Copper.

A new low record in the price of copper was established last week, falling to £30 6s. 3d. per ton, a price not previously experienced. There is no doubt that the action of the United States copper exporters is, in a measure, responsible for this new low level. Pegging the price at a level considered unjustifiable by customers has been responsible for the accumulation of large stocks of surplus metal, while the producers outside the cartel have been strong enough to render its efforts fruitless. With a knowledge of the huge stocks available, consumers have bought sparingly, when it has been possible, and the position has been further complicated by reduced demand resulting from the trade depression. There is no doubt, however, that large consumers suffer considerably as a result of the lack of stability, and the sooner the industry emerges from its present morass the better for everyone concerned.

Business Notes and News

Cast-iron Roads.

Many materials have been used to provide suitable and lasting surfaces for the faster and heavier traffic modern road transport involves; not all, however, have met with the success their originators anticipated. New developments are naturally expected from time to time, but it will probably surprise many that cast iron for this purpose is on trial. Some experimental sections have been in use for about twelve months, and these have met with such success that several more road authorities are proposing to lay further experimental sections. These sections are paved with cast-iron segments or slabs, and the amount of wear visible on them after twelve months is claimed to be infinitesimal, and not normally measurable. The surface formed is claimed to be absolutely non-skidding, and that the small studs, which are cast on the sections, give a remarkable grip to rubber tyres without in any way being detrimental to cycle tyres or cyclists. The studs also apparently provide a firm footing for horses and cattle.

The cost of paving a road with cast iron is said to be more expensive than with other materials now in common use. Apart from the foundations, the cost is about 6s. more per square yard, but to offset this extra cost it is claimed that cast-iron roads will last for ever. Further, no pot holes are formed, or unevenness of surface, no seasonal tarring is necessary, and repair work is claimed to be eliminated.

If these claims are substantiated there is no doubt that some stretches of road, subjected to heavy traffic, will be reconstructed to give a more severe trial to this new development. It is likely that the difference in cost will be considerably reduced if the cast-iron sections or slabs are produced on a mass-production plan. Some economy would certainly be effected by using metal direct from the blast furnace There are immense possibilities about this development, and the prospects are apparently good.

Cranes Shipped from the Tyne.

The second part of an important engineering order, secured by Messrs. Clarke, Chapman and Co., Ltd., was shipped from the Tyne recently. The order was for four large cranes to be used for handling coal on the Mole at Gibraltar, which are being constructed for the Gibraltar Transport Co. Each crane, which is supported on a bridge structure 120 ft. long, has an operating radius of 57 ft., and each is fitted with a grab with a capacity to lift 2½ tons of coal. The crane is capable of dealing with 150 tons of coal per hour. The four cranes will involve 700 tons of steelwork and machinery, of which this consignment represents about 175 tons. When these cranes have been completed and erected the facilities for the rapid coaling of vessels calling at Gibraltar will be of a high order.

Modern Optical Instruments on View.

A loan exhibition of modern British optical instruments is to take place in the Science Museum, South Kensington, during the time of the British Association Centenary meeting, September 23—30, and apparatus has been lent by a number of leading manufacturers in this country. The display will be on view until October 31 in the optical-instrument gallery, and popular demonstrations will take place at intervals. About 100 exhibits are shown, including binoculars, range-finders, photographic and microscopic objectives, projection-microscopes, and surveying instruments. Aerial cameras, microphotometers, spectrographs, and a cinema projector are among the developments of optical technique to be illustrated, and demonstrations are to be given at intervals.

Blast Furnace Damped Down.

The last blast furnace in operation at the Trent Ironworks, Scunthorpe, is to be damped down shortly, we understand. The Trent works are owned by Messrs. Firth, Brown and Co., Ltd., of Sheffield, and under normal conditions two of their three blast furnaces are working. Only one of these furnaces has been operating for some time, and owing to accumulation of stocks, as a result of bad trade, this furnace is also to cease operations. The Trent works will be the third to be closed at Scunthorpe during the last two years. Only two firms in the district will be working, namely, the Frodingham and Appleby Iron and Steel Works of the United Steel Companies, Ltd., and the Normanby Park Iron and Steel Works of Messrs. John Lysaght, Ltd.

British Exports Decline.

It is many years since British overseas trade, both imports and exports, reached such a low ebb as it did in August. In July it showed a welcome advance in manufactured goods, the total for June being exceeded by £4,800,000. The total exports of United Kingdom produce and manufactures amounted to £34,250,000, as compared with £29,400,000 in June, and there was also an improvement in the import trade from £68,640,000 to £70,145,000. The re-export trade, however, showed an appreciable decline of over £1,000,000.

This recovery of exports in July from the dismal figures of the previous month was not maintained in August, the returns showing in fact that an even lower level had been reached than in June. In the case of iron and steel imports declined from £1,557,035 in July to £1,357,804 in August, and machinery from £1,227,093 to £1,051,329. During the same periods exports of iron and steel declined from £2,599,030 to £2,173,946, and machinery from £2,693,365 to £2,174,262.

MARKET PRICES

ALUMINIUM.

99% Purity	£85	0	0

ANTIMONY.

English	£34	0	0
Chinese	21	15	0
Crude	20	0	0

BRASS.

Solid Drawn Tubes	lb.	9d.
Brazed Tubes	lb.	11d.
Rods Drawn	,,	7½d.
Wire	,,	7¾d.
*Extruded Brass Bars	,,	4d.

COPPER.

Standard Cash	£30	11	3
Electrolytic	34	10	0
Best Selected	32	10	0
Tough	32	0	0
Sheets	64	0	0
Wire Bars	37	2	6
Ingot Bars	37	2	6
Solid Drawn Tubes	lb.		10d.
Brazed Tubes	,,		10d.

FERRO ALLOYS.

‡Tungsten Metal Powder	lb.	0	1	11½
‡Ferro Tungsten	,,	0	1	8½
§ Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
2-4% Carbon, scale 11/- per unit	ton	28	0	0
4-6% Carbon, scale 7/- per unit	,,	20	0	0
6-8% Carbon, scale 7/- per unit	,,	19	17	6
8-10% Carbon, scale 7/- per unit	,,	19	2	6
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steelwork. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 10/- per unit	,,	29	0	0
Guar. max. 1% Carbon, scale 13/6 per unit	,,	32	17	6
§Guar. max. 0.7% Carbon, scale 15/- per unit	,,	36	10	0
‡Manganese Metal 96-98% Mn.	lb.	0	1	3
‡Metallic Chromium	,,	0	2	7
§ Ferro-Vanadium 25-50%	,,	0	12	8
§ Spiegel, 18-20%	ton	6	17	6
Ferro Silicon—				
Basis 10%, scale 3/- per unit	ton	5	17	6
20/30% basis 25%, scale 3/- per unit	,,	7	0	0
45/50% basis 45%, scale 5/- per unit	,,	9	12	6
70/80% basis 75%, scale 7/- per unit	,,	15	17	6
90/95% basis 90%, scale 10/- per unit	,,	23	12	6
§ Silico Manganese 65/75% Mn., basis 65% Mn.	,,	11	5	0
§ Ferro-Carbon Titanium, 15/18% Ti	lb.	0	0	6
Ferro Phosphorus, 20-25%	ton	15	5	0

FUELS.

Foundry Coke—						
S. Wales Export	£1	2	0 to	£1	16	6
Sheffield Export	0	14	0 to	0	15	0
Durham Export			1	4	0	
Furnace Coke—						
Sheffield Export	0	14	0 to	0	15	0
S. Wales ,,	0	16	6 to	0	17	6
Durham			0	13	0	

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)	£47	10	0
*Commercial Ingots	39	10	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0	0 9
*Cored Bars	,,	0	0 11

LEAD.

Soft Foreign	£10	13	9
English	12	5	0

MANUFACTURED IRON.

Scotland—			
Crown Bars	£10	5	0
N.E. Coast—			
Rivets	11	5	0
Best Bars	11	0	0
Common Bars	10	10	0
Lancashire—			
Crown Bars	9	15	0
Hoops	12	0	0
Midlands—			
Crown Bars £9 5 0 to	10	7	6
Marked Bars	12	0	0
Unmarked Bars		—	
Nut and Bolt Bars £8 10 0 to	9	0	0
Gas Strip	10	12	6
S. Yorks.—			
Best Bars	10	15	0
Hoops	12	0	0

PHOSPHOR BRONZE.

*Bars, "Tank" brand, 1 in. dia. and upwards	lb.	9d.
*Cored Bars	,,	11d.
†Strip	,,	10½d.
†Sheet to 10 W.G.	,,	10¾d.
†Wire	,,	11¾d.
†Rods	,,	11d.
†Tubes	,,	1/4
†Castings	,,	1/1

†10% Phos. Cop. £30 above B.S.
†15% Phos. Cop. £35 above B.S.
†Phos. Tin (5%) £30 above English Ingots.

PIG IRON.

Scotland—			
Hematite M/Nos.	£3	8	6
Foundry No. 1	3	12	0
,, No. 3	3	9	6
N.E. Coast—			
Hematite No. 1	3	0	6
Foundry No. 1	3	1	0
,, No. 3	2	18	6
,, No. 4	2	17	6
Cleveland—			
Foundry No. 3	2	18	6
,, No. 4	2	17	6
Silicon Iron	3	1	0
Forge No. 4	2	17	0
N.W. Coast—			
Hematite	4	4	6
Midlands—			
N. Staffs Forge No. 4	3	1	0
,, Foundry No. 3	3	6	0
Northants—			
Forge No. 4	2	17	6
Foundry No. 3	3	2	6
Derbyshire Forge	3	1	0
,, Foundry No. 3	3	6	0
West Coast Hematite	4	2	6
East ,, ,,	4	0	0

SWEDISH CHARCOAL IRON AND STEEL.

Pig Iron	£6	0	0 to	£7	10	0
Bars, hammered, basis	£17	10	0 ,,	£18	10	0
Blooms	£10	0	0 ,,	£12	0	0
Keg steel	£32	0	0 ,,	£33	0	0
Faggot steel	£20	0	0 ,,	£24	0	0

All per English ton, f.o.b. Gothenburg.

SCRAP METAL.

Copper Clean	£25	0	0
,, Braziery	22	0	0
,, Wire		—	
Brass	18	0	0
Gun Metal	22	0	0
Zinc	4	10	0
Aluminium Cuttings	52	0	0
Lead	9	0	0
Heavy Steel—			
S. Wales	2	0	0
Scotland	1	17	6
Cleveland	1	17	6
Cast Iron—			
Lancashire	2	5	0
S. Wales £2 0 0 to	2	2	6
Cleveland £2 0 0 to	2	2	0
Steel Turnings—			
Cleveland	1	5	0
Lancashire	1	0	0
Cast Iron Borings—			
Cleveland	1	2	0
Scotland	1	10	0

SPELTER.

G.O.B. Official		—	
Hard	£8	10	0
English	11	12	6
India	10	10	0
Re-melted	10	10	0

STEEL.

Ship, Bridge, and Tank Plates—			
Scotland	£8	15	0
North-East Coast	8	15	0
Midlands	8	17	6
Boiler Plates (Land), Scotland	10	10	0
,, ,, (Marine) ,,	10	10	0
,, ,, (Land), N.E. Coast	10	0	0
,, ,, (Marine) ,,	10	10	0
Angles, Scotland	8	7	6
,, North-East Coast	8	7	6
,, Midlands	8	7	6
Joists	8	15	0
Heavy Rails	8	10	0
Fishplates	12	0	0
Light Rails £8 10 0 to	8	15	0
Sheffield—			
Siemens Acid Billets	9	2	6
Hard Basic £8 2 6 and	8	12	6
Medium Basic £6 12 6 and	7	2	6
Soft Basic	6	0	0
Hoops £9 10 0 to	9	15	0
Manchester—			
Hoops £9 0 0 to	10	0	0
Scotland, Sheets 20 W.G.	9	10	0

HIGH SPEED TOOL STEEL.

Finished Bars 18% Tungsten. Extras	lb.	2/9
Round and Squares, ¼ in. to ½ in.	,,	3d.
Under ¼ in. to ⅛ in.	,,	1/-
Round and Squares 3 in.	,,	4d.
Flats under 1 in. × ¾ in.	,,	3d.
,, ,, ½ in. × ¼ in.	,,	1/-

TIN.

Standard Cash	£113	17	6
English	115	10	0
Australian	115	0	0
Eastern	119	10	0
Tin Plates I.C. 20 × 14 box	13/- to 13/3		
Block Tin Cash	£114	10	0

ZINC.

English Sheets	£20	10	0
Rods	22	0	0
Battery Plates	16	5	0

* McKechnie Brothers, Ltd., quoted Sept. 10. † C. Clifford & Son, Ltd., quoted Sept. 10. ‡Murex Limited, quoted Sept. 10.

Subject to Market fluctuations, Buyers are advised to send inquiries for current prices.

Lancashire Steel Corporation's Current Basis Prices, f.o.b. Liverpool or Stations in Lancashire :—Wrought Iron Bars, £9 15s. 0d.; Mild Steel Bars, £6 10s. 0d.; Wrought Iron Hoops, £11 10s.; Best Special Steel Baling Hoops, £8 5s. 0d.; Soft Steel Hoops (Coopers' and Ordinary Qualities), £7 15s. 0d.; C. R. & C. A. Steel Hoops, £11 10s. 0d. "Iris" Bars, £8 5s. 0d. All Nett Cash. Quoted Sept. 10. § Prices quoted Sept. 10, ex warehouse.